SECOND EDITION

ECG In 10 Days

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David R. Ferry

ECG in 10 Days

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This book is dedicated to my good friend, mentor,
and role model, Dr. Glenn L. Foster, cardiologist
and former Chief of Medicine at the
Loma Linda VA Healthcare System.
He taught me that patience, humanity, dignity,
precision, integrity, and spirituality were essential
to the practice of medicine and the living of life.

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Preface

This book originally arose from our commitment to teach senior medical students how to interpret electrocardiograms in two weeks, or ten working days. The School of Medicine, in its wisdom, had chosen that interval for us, and we were forced to adapt to its mandate. We had 10 to 15 students in our class every four weeks for the entire academic year. We quickly realized that we needed to establish specific topics for each day so that, regardless of which faculty members were available, there was a consistent method used. We also decided on a set of sample ECGs to use each day.

I found myself repeatedly drawing the same illustrations, charts, and diagrams, so I eventually put together the rudiments of this text into a handout. This effort was well received by medical students, residents from Internal Medicine, Family Practice, and Preventive Medicine, and nurses and technicians. I was subsequently encouraged to publish this material, and the editors at McGraw-Hill were gracious enough to accommodate me.

Since publication of the first edition, several things have become obvious, particularly that I needed to provide many more sample ECGs for practice, both at the end of the chapters and a random sample at the end of the text. Therefore, there are now 20 ECGs at the ends of Chapters 2–9 and 100 at the end, bringing the total practice tracings to 280, far more than any other book. I needed to update several figures and add many more to accommodate advances in electrocardiography and make some concepts easier to understand. It was obvious that I needed to divide the contents of Day 5 into two chapters, therefore necessitating compression of Days 2 and 3 into one chapter. I also decided to use full 12 lead ECGs instead of rhythm strips to illustrate the majority of concepts, since it would be in this format that practitioners would encounter these tracings. Finally, I decided to use a system I call "call-outs" on the sample ECGs, in which key portions of the tracing are identified by circles and are then enlarged and commented on in the top margin.

There have also been major advances in computer imaging, processing, and storage since the first text. In this edition, all of the illustrations were drawn on an Apple Macintosh G5 computer using Adobe PhotoShop CS2

and a Wacom graphics tablet. The ECGs were scanned at 600 dpi for clarity even when magnified in the call-outs.

It is my hope that my readers will enjoy this text as much as I did in preparing it and in teaching the concepts.

David R. Ferry, MD

Acknowledgments

I would like to thank my colleagues at the Loma Linda VA Healthcare Center, Drs. Geir P. Frivold, Gary P. Foster, Alan K. Jacobson, Helme Silvet, Patricia M. Applegate, and Paul A. Levine, for their constant encouragement, suggestions, and corrections. Many of the features of this text are the result of quiet, continuous gentle pressure applied by my friend Geir Frivold. The medical students made countless suggestions about ways to improve the first edition and told me what worked and what did not. My wife, Dr. Linda H. Ferry, was her usual source of wisdom and inspiration. My editor at McGraw-Hill, Quincy McDonald and project manager at ITC, Gita Raman, patiently worked with me to keep the book on schedule and the quality high. Finally, I will never forget my teachers and mentors from my fellowship days, Drs. Michael H. Crawford and Robert A. O'Rourke.

Suggestions for Using This Book

This book is arranged in a progressive manner, starting with basic concepts and increasing in complexity with the study of arrhythmias on Days 5–8. The final two chapters cover miscellaneous topics and an introduction to electronic pacemakers. I suggest that the reader study the text and illustrations for each day in depth, and then interpret the electrocardiograms at the end of each chapter. The 100 tracings at the end of the text can be used to test one's understanding of all of the material, particularly prior to taking examinations.

Be systematic! Use the protocol suggested at the end of Day 1 and follow it rigorously. Using a system has two benefits: it forces the interpreter to be thorough and not overlook diagnoses, and it promotes organization of thought which will likely lead to a diagnosis.

Since this text represents the efforts of many collaborators and should be considered a work in progress; suggestions for future editions would be greatly appreciated. Please contact me at:

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Day 1

The Basics

I. Cardiac muscle has two unique properties that predispose it to the two common types of arrhythmias

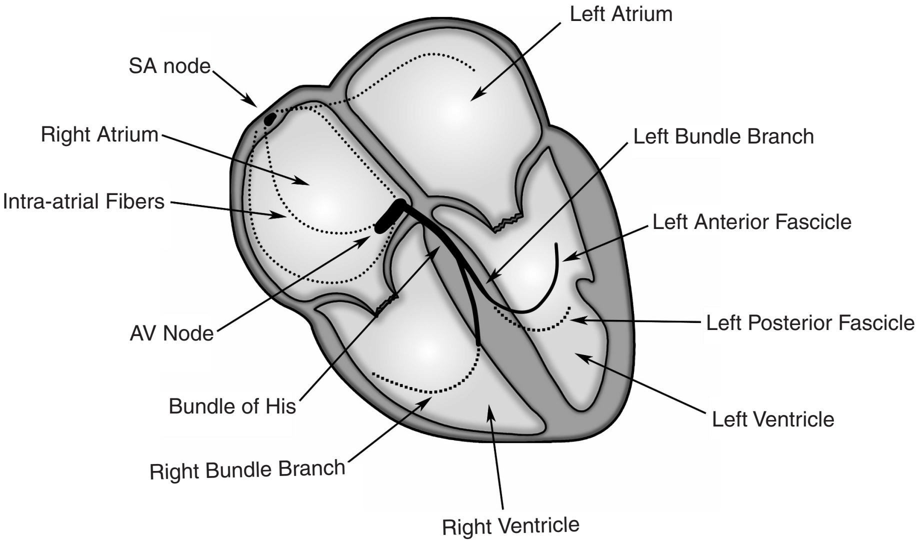
   A. Automaticity
      1. As opposed to skeletal muscle, all myocardial cells exhibit spontaneous depolarization.
      2. This is normally a beneficial property because:
         a. It obviates the need for central nervous system initiation of myocardial depolarization.
         b. It allows for “backup” pacemakers to take over if there is sinus node dysfunction or failure of propagation of depolarization.
      3. Disorders of this property can result in *automatic* or *ectopic arrhythmias.*

   B. Gap junction transmission
      1. Again, as opposed to skeletal muscle, myocardial cells can transmit electrical signals from one to another via gap junctions.
      2. This is normally beneficial as nervous tissue is not required for the propagation of depolarization.
      3. However, as will be seen, the requirements for *reentrant arrhythmias* include having at least two pathways for electrical current, a condition facilitated by gap junctions.

II. Components of the conduction system

   A. The conduction system consists of modified cardiac muscle cells that have unique electrical properties.

   B. Sinoatrial (SA) node
      1. The SA node is a collection of cells in the upper right corner of the right atrium.
      2. The SA node controls the rhythm of the heart by virtue of having the fastest intrinsic rate of depolarization (60–100 beats/min).
      3. The SA node starts the cardiac cycle by initiating atrial systole.



C. The atrioventricular (AV) node
   1. The AV node is located near the inferior portion of the interatrial septum.
   2. The AV node serves two functions:
      a. It provides a physiological conduction delay to allow the atria to fill the ventricles prior to ventricular systole.
      b. It also protects the ventricles from excessive stimulation from the atria, such as in atrial fibrillation.

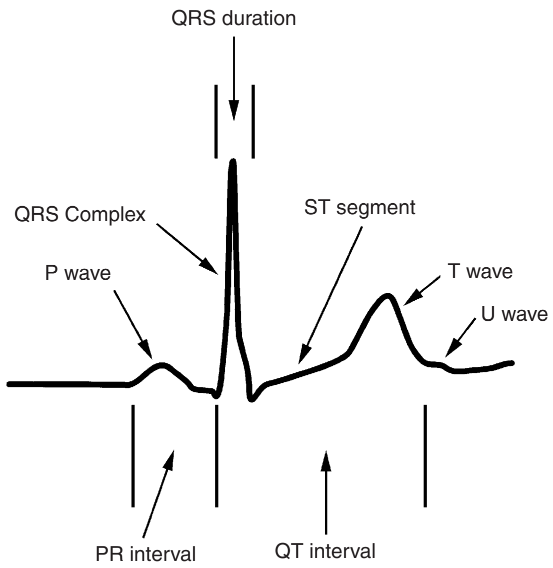
D. The His-Purkinje system
   1. The His bundle divides into the right and left bundles.
   2. The left bundle further divides into the left anterior and posterior fascicles.
   3. The His-Purkinje system provides for the orderly depolarization of the ventricles.

III. Genesis of the surface electrocardiogram (ECG)

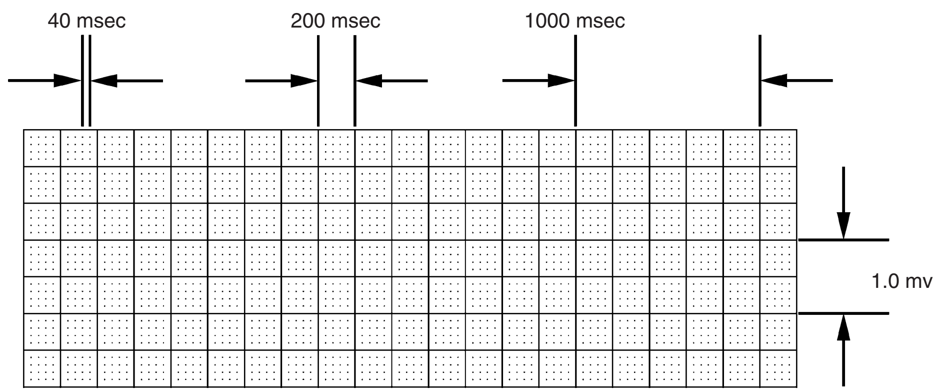
A. A wave of negative electric potential spreads across contracting myocardium.

B. This potential can be detected by electrodes placed at various locations on the skin, the signal amplified, and displayed as an ECG.

C. The components of the ECG represent various cardiac events.
   1. The P wave corresponds to atrial systole.
   2. The PR interval represents the physiological delay in the AV node and His bundle.
   3. The QRS complex results from ventricular systole.
   4. The T wave represents ventricular repolarization.
   5. The cause of the inconsistently present U wave is controversial.



D. The ECG paper
1. The ECG is recorded on moving paper ruled at 1 mm intervals with darker lines every 5 mm.
2. At the standard paper speed of 25 mm/sec, each I mm horizontally represents 40 msec and each 5 mm interval 200 msec.
3. In the vertical dimension, each 10 mm represents 0.1 mv of electrical potential.

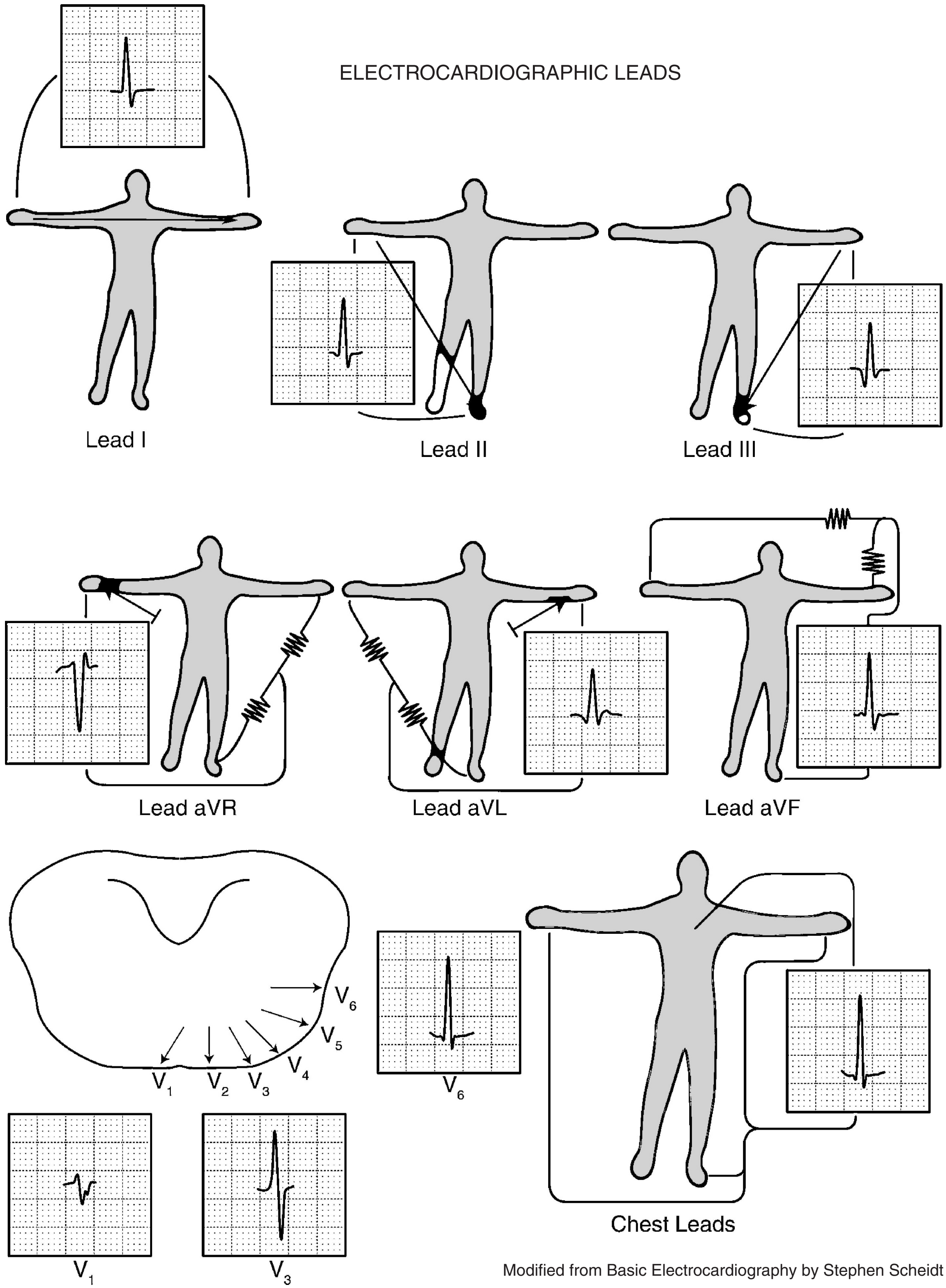


IV. The standard ECG leads

A. There are six standard leads (the "limb leads") that depict cardiac electrical events from six angles in the frontal or vertical plane.

B. There are six precordial leads (the "chest leads") that depict electrical events in the horizontal plane.

ELECTROCARDIOGRAPHIC LEADS

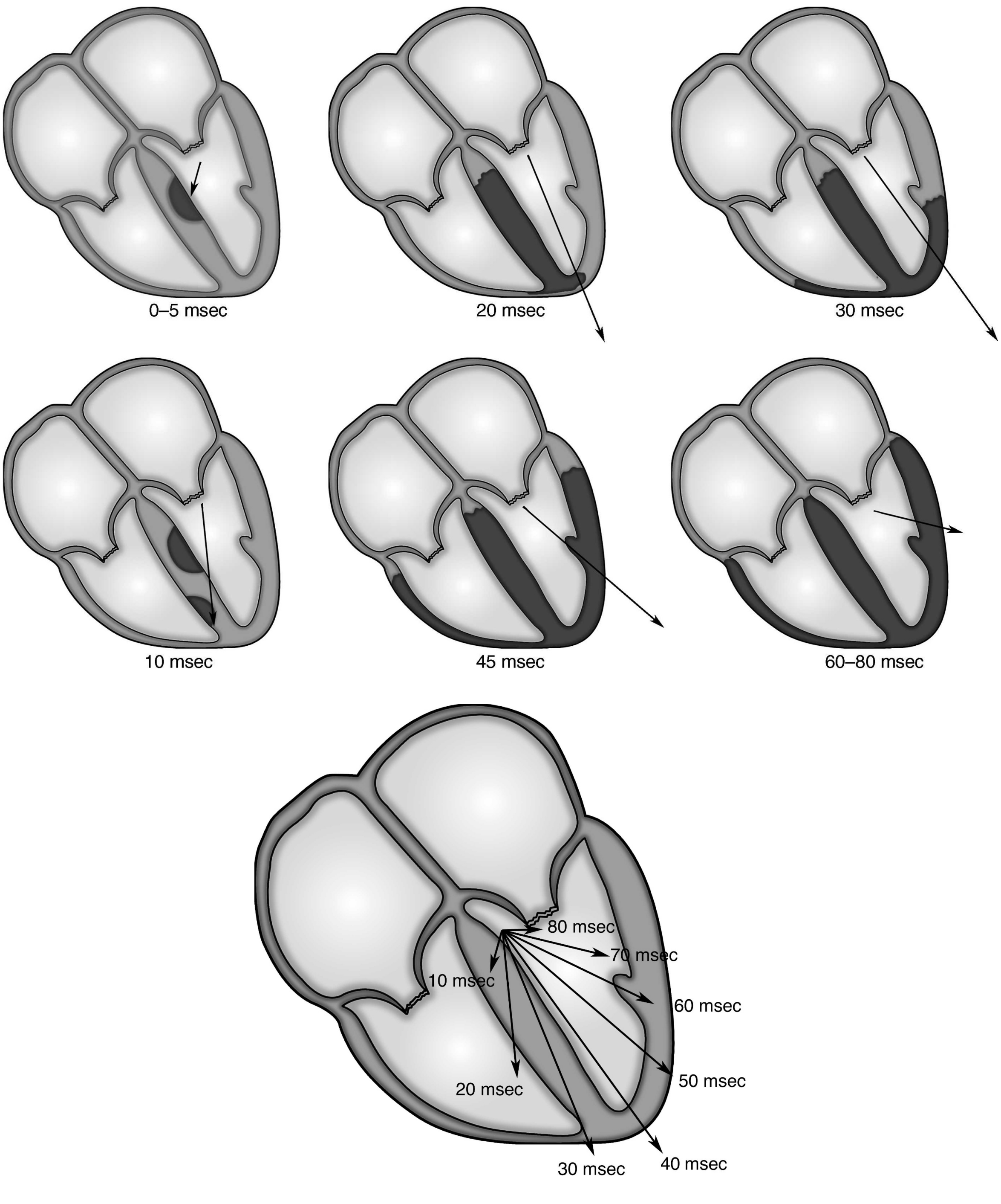


Modified from Basic Electrocardiography by Stephen Scheidt

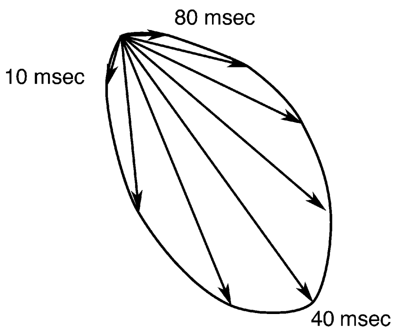
V. Genesis of the ECG wave forms in the various leads and the concept of axis

A. The P wave, QRS complex, and T wave for any lead can be derived from the vector representation of electrical activity in the appropriate plane.

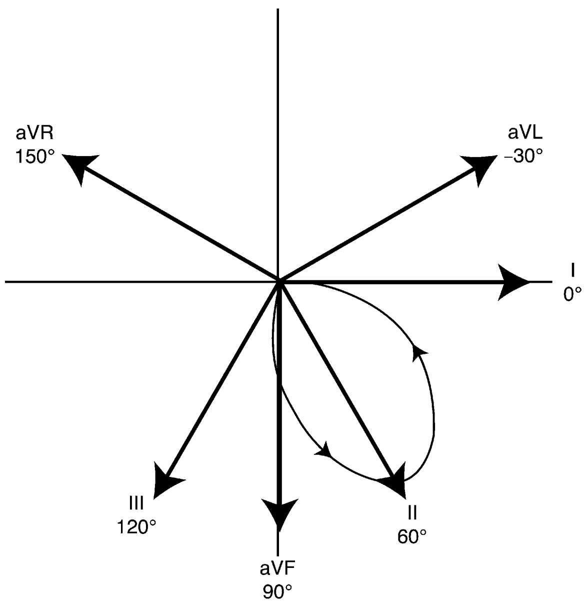
1. For instance, ventricular depolarization in the frontal plane can be displayed by a series of vectors representing the mathematical sum of all the electrical activity occurring at that instant.



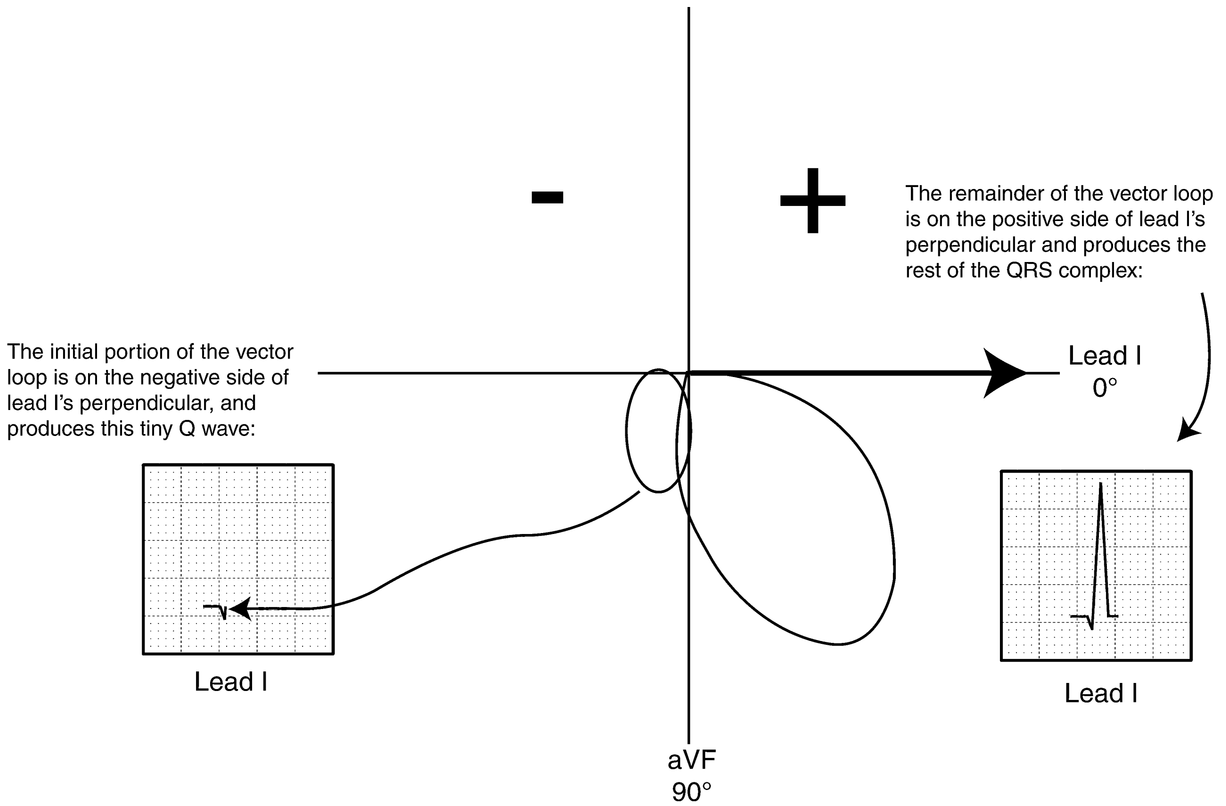
2. The tips of these vectors can be connected to form a loop.

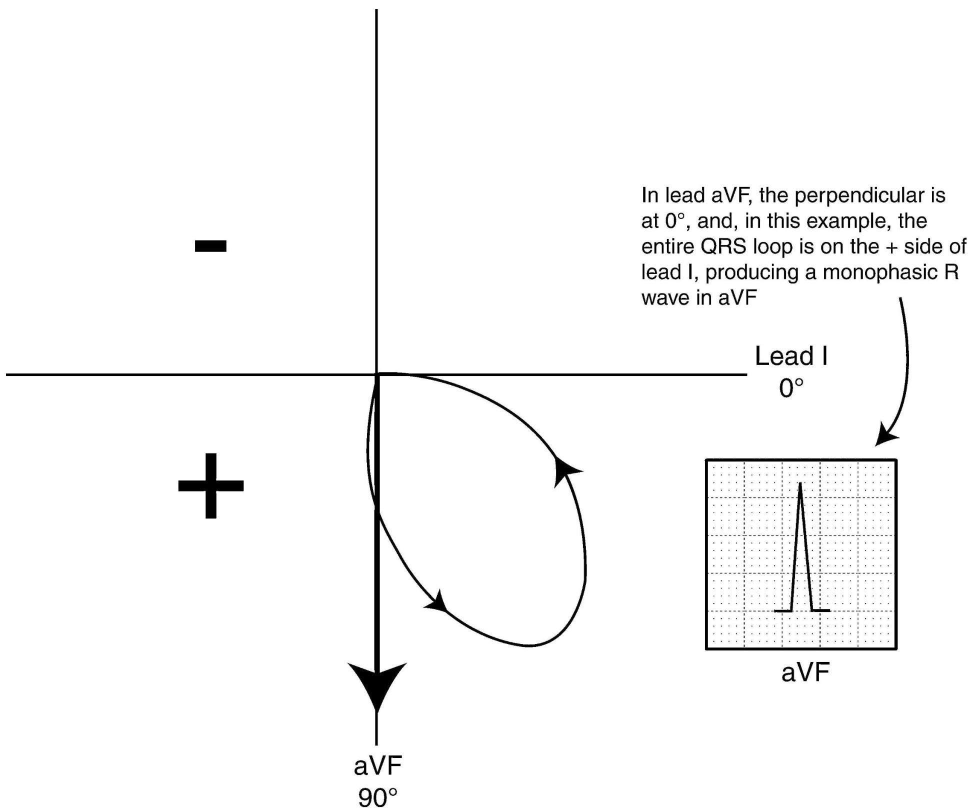


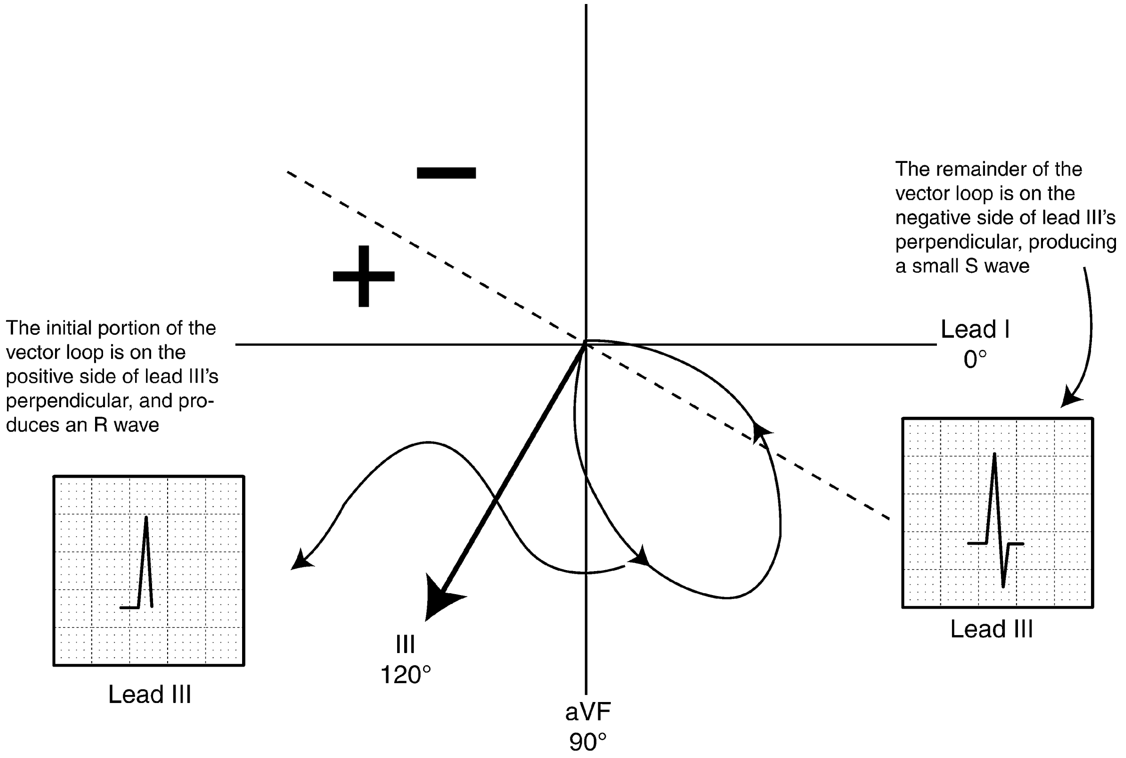
3. The loop can be superimposed on the frontal plane axis.



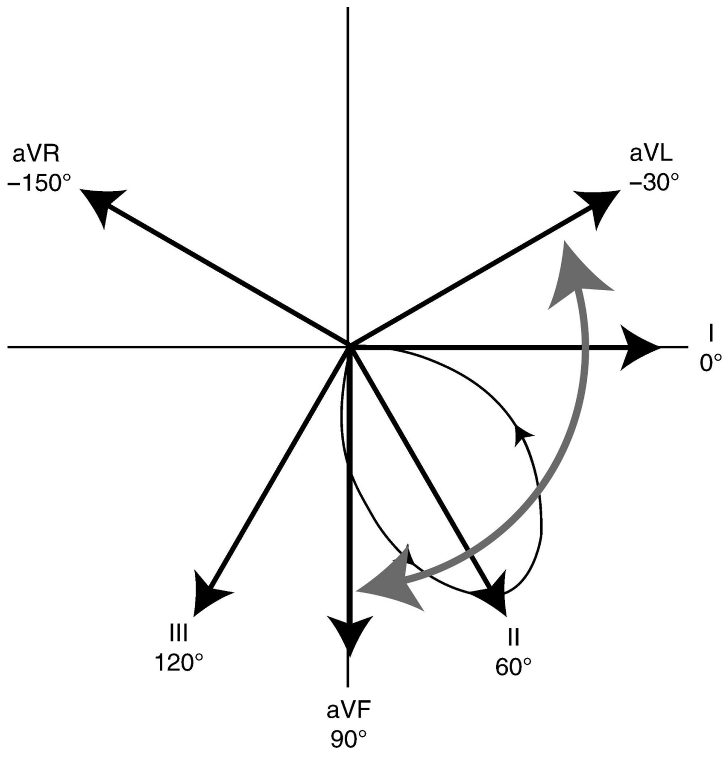
a. To form the QRS complex of Lead I, a line is drawn perpendicular to that lead.
b. By convention, all electrical forces on the side of the perpendicular towards Lead I are designated as positive, and those away as negative.

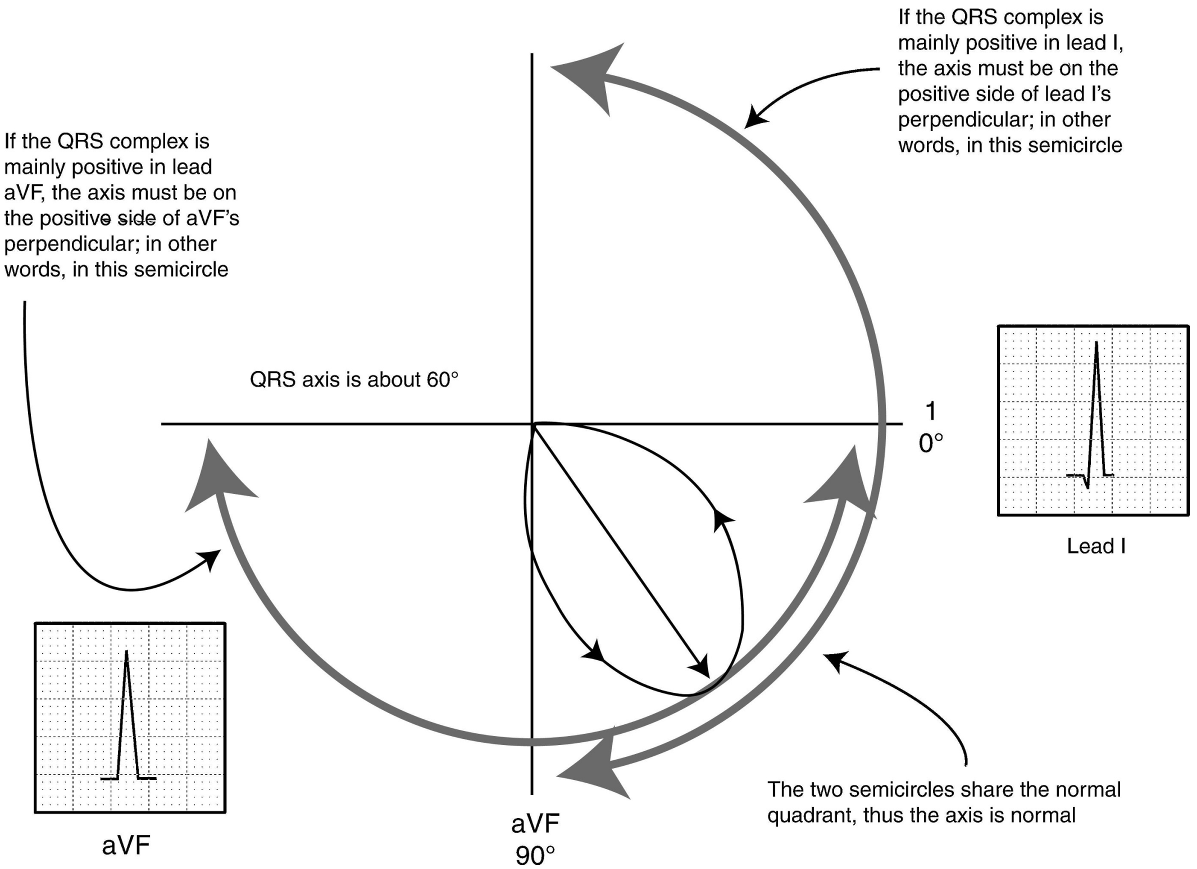

-
+
The remainder of the vector loop is on the positive side of lead I's perpendicular and produces the rest of the QRS complex:
The initial portion of the vector loop is on the negative side of lead I's perpendicular, and produces this tiny Q wave:
Lead I
0°
Lead I
Lead I
aVF
90°

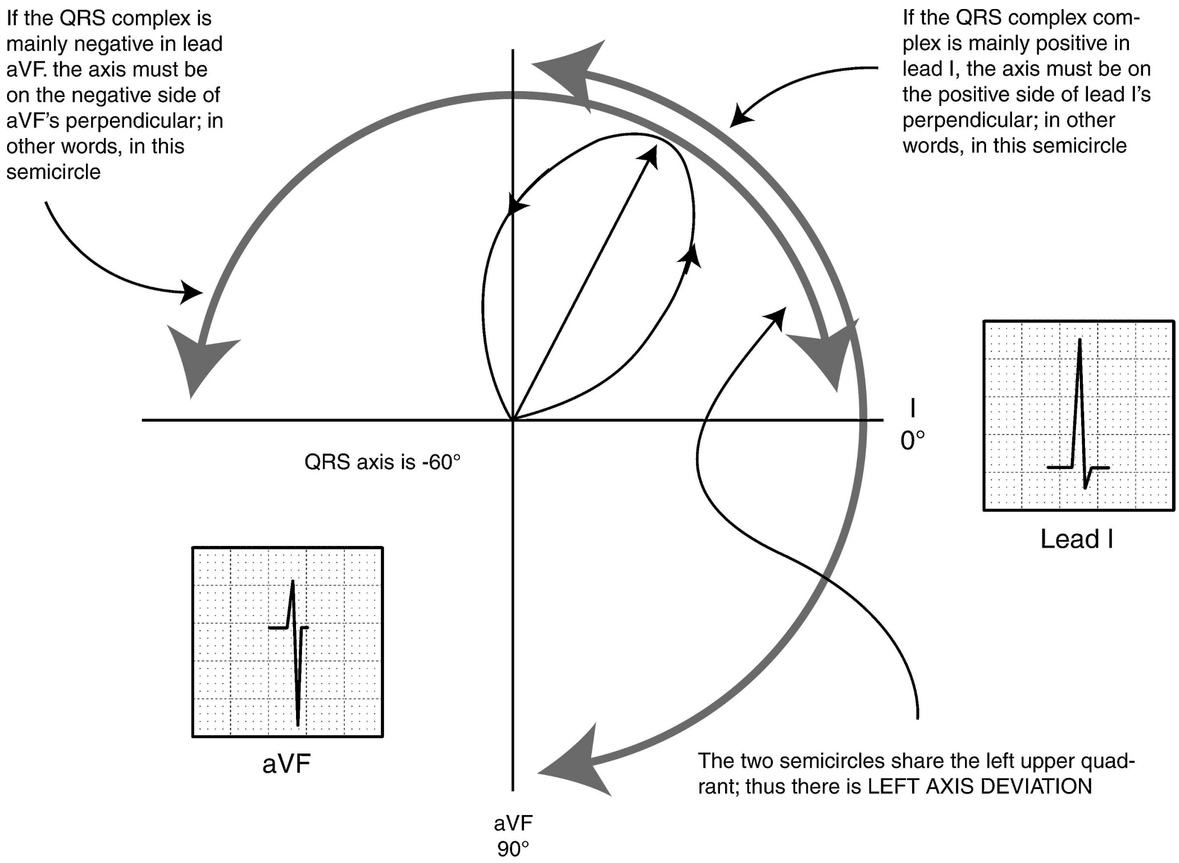

-
+
In lead aVF, the perpendicular is at 0°, and, in this example, the entire QRS loop is on the + side of lead I, producing a monophasic R wave in aVF
Lead I
0°
aVF
aVF
90°

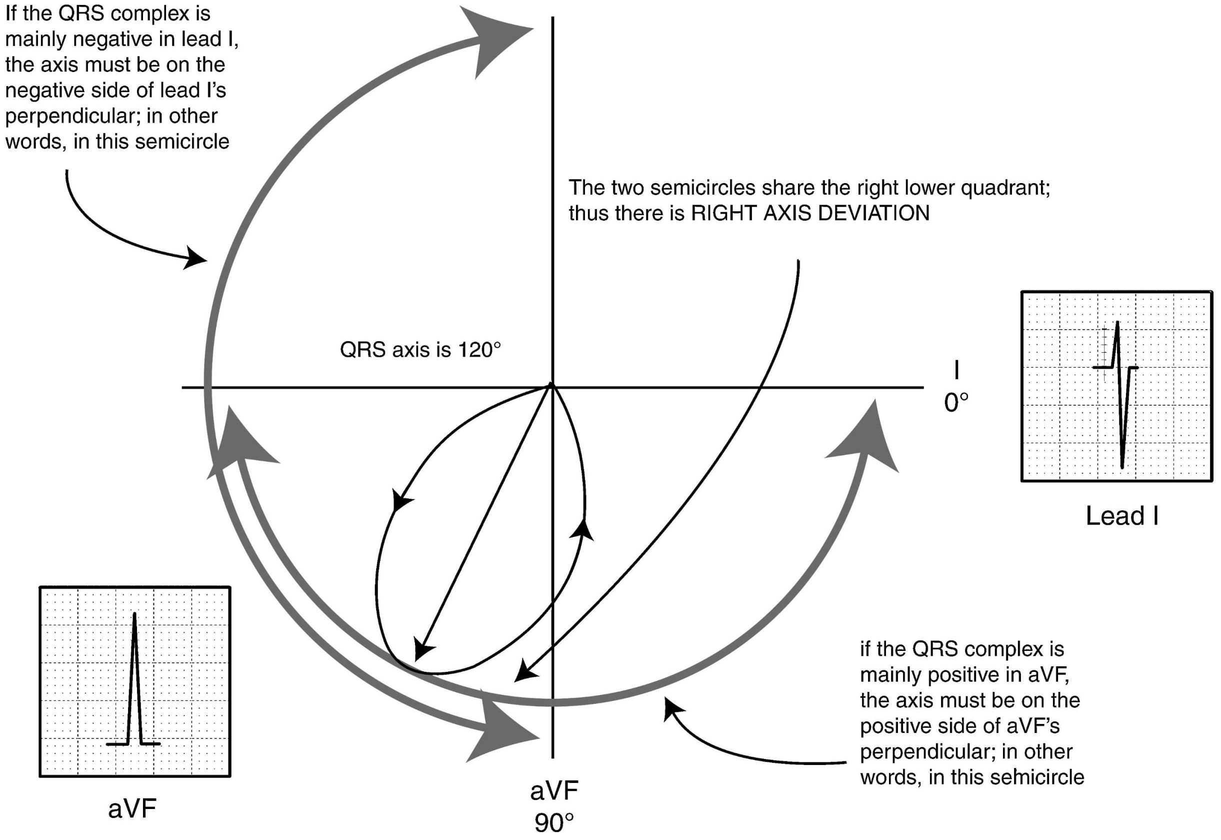


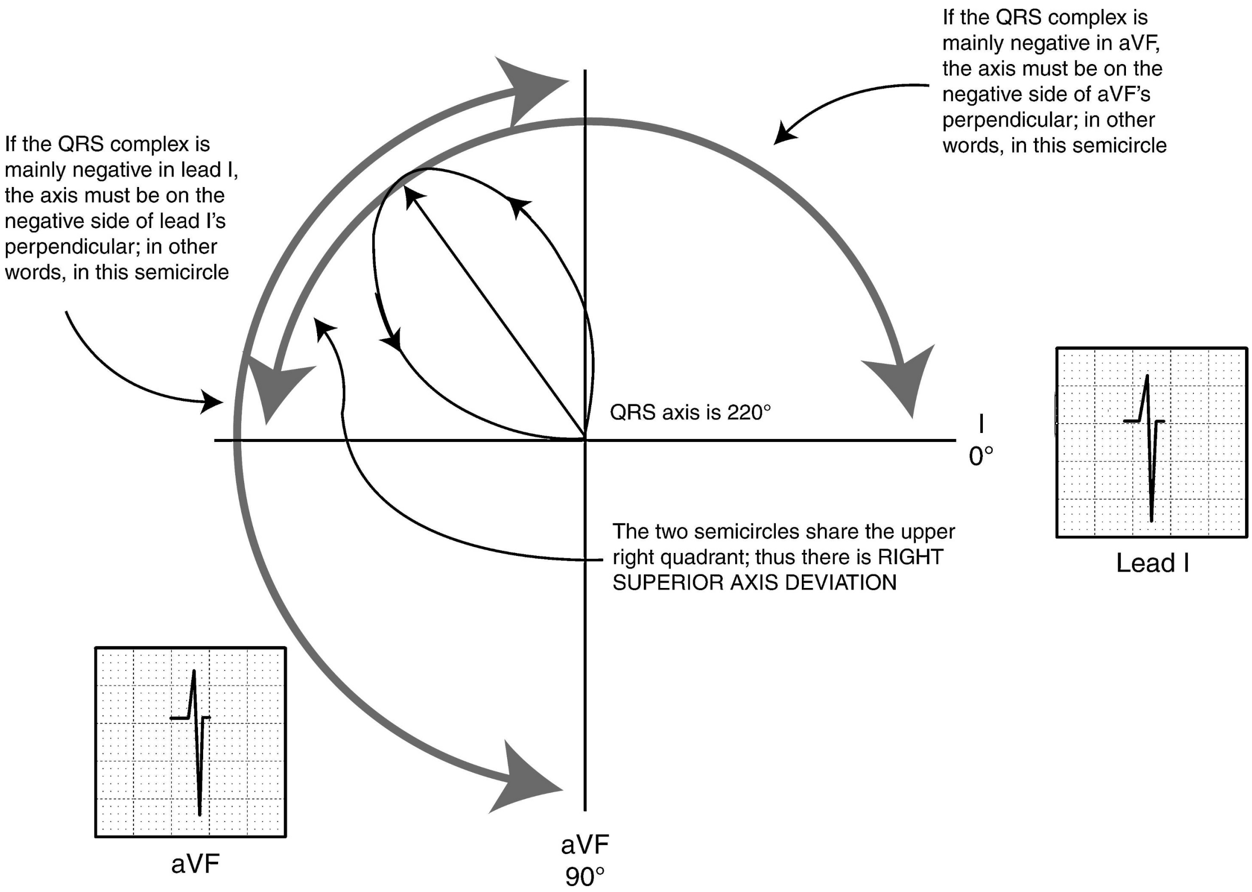
B. The electrical axis is the sum of all the vectors in that plane.
   1. The normal QRS axis is between −30° and +90°.
   2. An easy way to determine the QRS axis is normal is to examine Leads I and aVF, and, if necessary, Lead II.

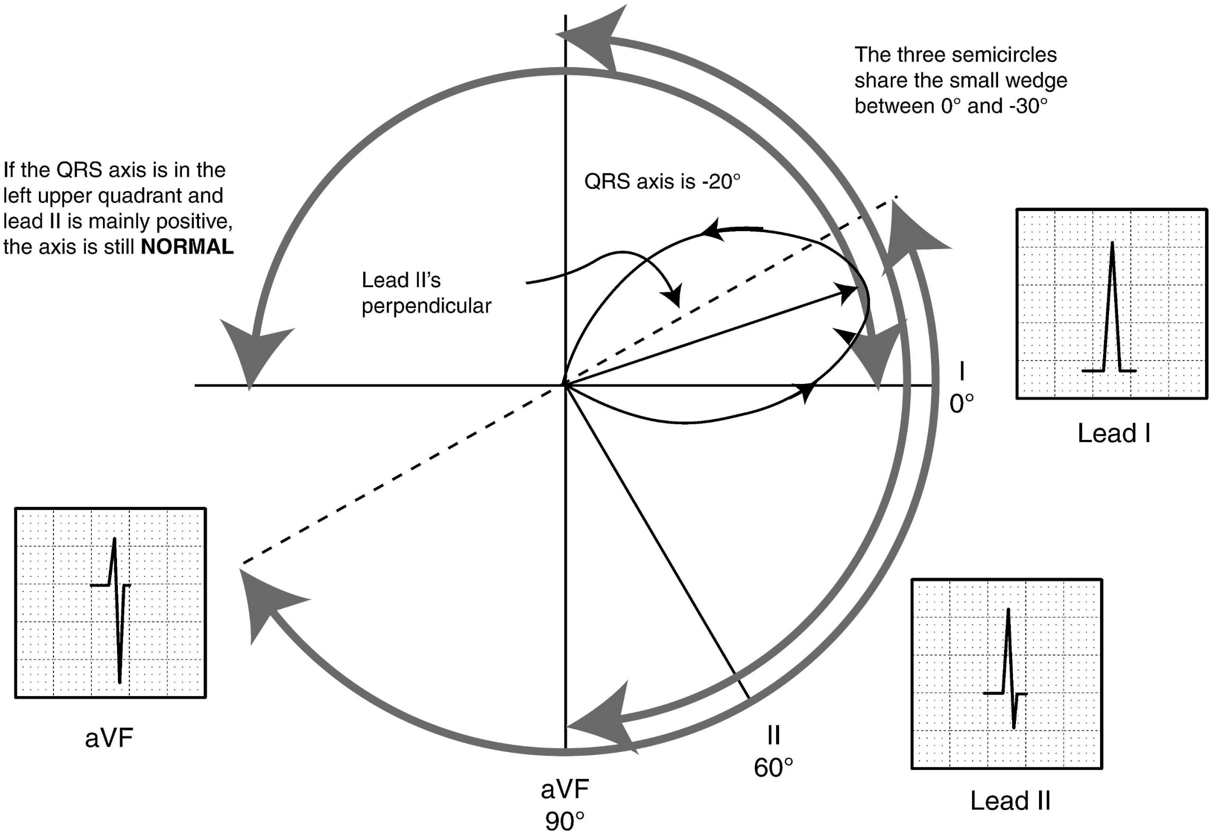



If the QRS complex is mainly positive in lead I, the axis must be on the positive side of lead I's perpendicular; in other words, in this semicircle
If the QRS complex is mainly positive in lead aVF, the axis must be on the positive side of aVF's perpendicular; in other words, in this semicircle
QRS axis is about 60°
1
0°
Lead I
aVF
aVF
90°
The two semicircles share the normal quadrant, thus the axis is normal

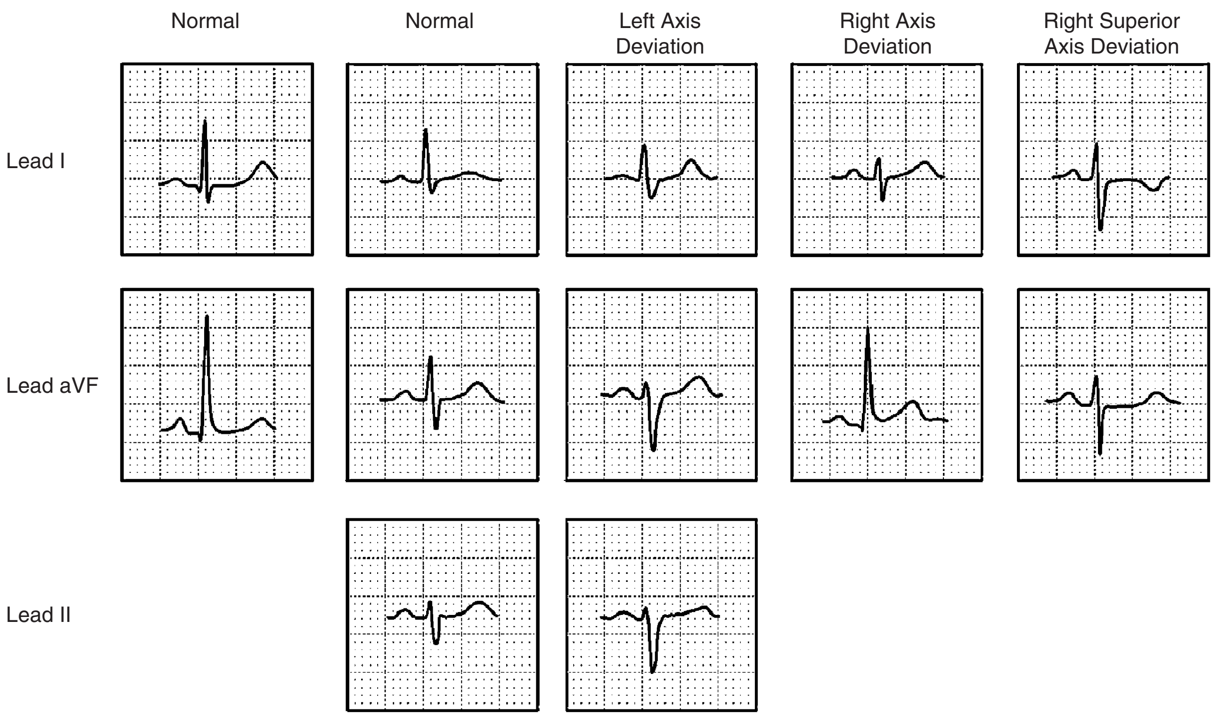

If the QRS complex is mainly negative in lead aVF. the axis must be on the negative side of aVF's perpendicular; in other words, in this semicircle
If the QRS complex complex is mainly positive in lead I, the axis must be on the positive side of lead I's perpendicular; in other words, in this semicircle
I
0°
QRS axis is -60°
Lead I
aVF
The two semicircles share the left upper quadrant; thus there is LEFT AXIS DEVIATION
aVF
90°


If the QRS complex is mainly negative in lead I, the axis must be on the negative side of lead I's perpendicular; in other words, in this semicircle
The two semicircles share the right lower quadrant; thus there is RIGHT AXIS DEVIATION
QRS axis is 120°
I
0°
Lead I
aVF
aVF
90°
if the QRS complex is mainly positive in aVF, the axis must be on the positive side of aVF's perpendicular; in other words, in this semicircle


If the QRS complex is mainly negative in aVF, the axis must be on the negative side of aVF's perpendicular; in other words, in this semicircle
If the QRS complex is mainly negative in lead I, the axis must be on the negative side of lead I's perpendicular; in other words, in this semicircle
QRS axis is 220°
I
0°
Lead I
The two semicircles share the upper right quadrant; thus there is RIGHT SUPERIOR AXIS DEVIATION
aVF
aVF
90°



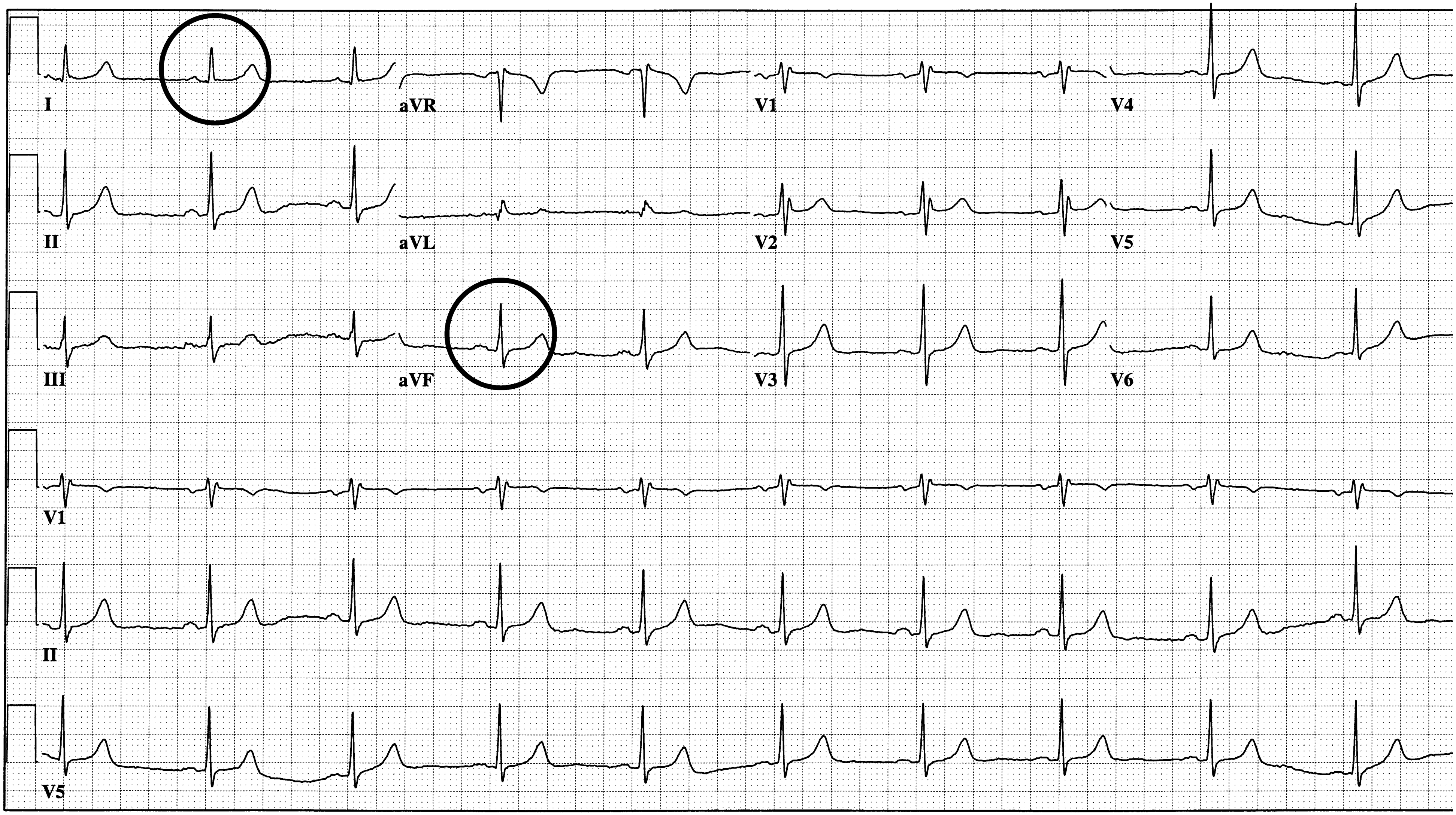
3. Summary and examples of QRS axes.



SUMMARY OF QRS AXES

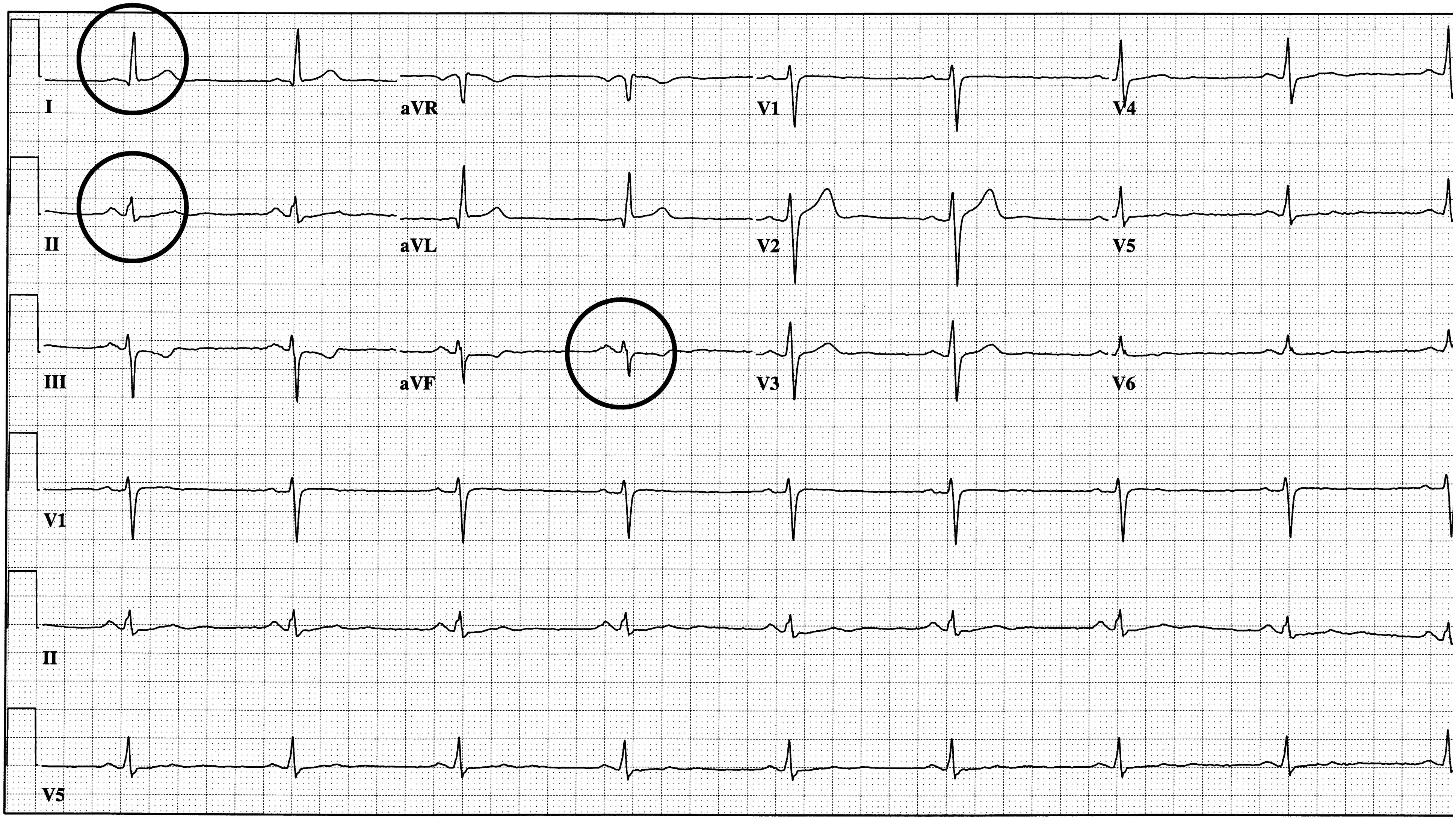
DAY 1-01

Normal QRS axis. The QRS complexes are upright in leads I and aVF



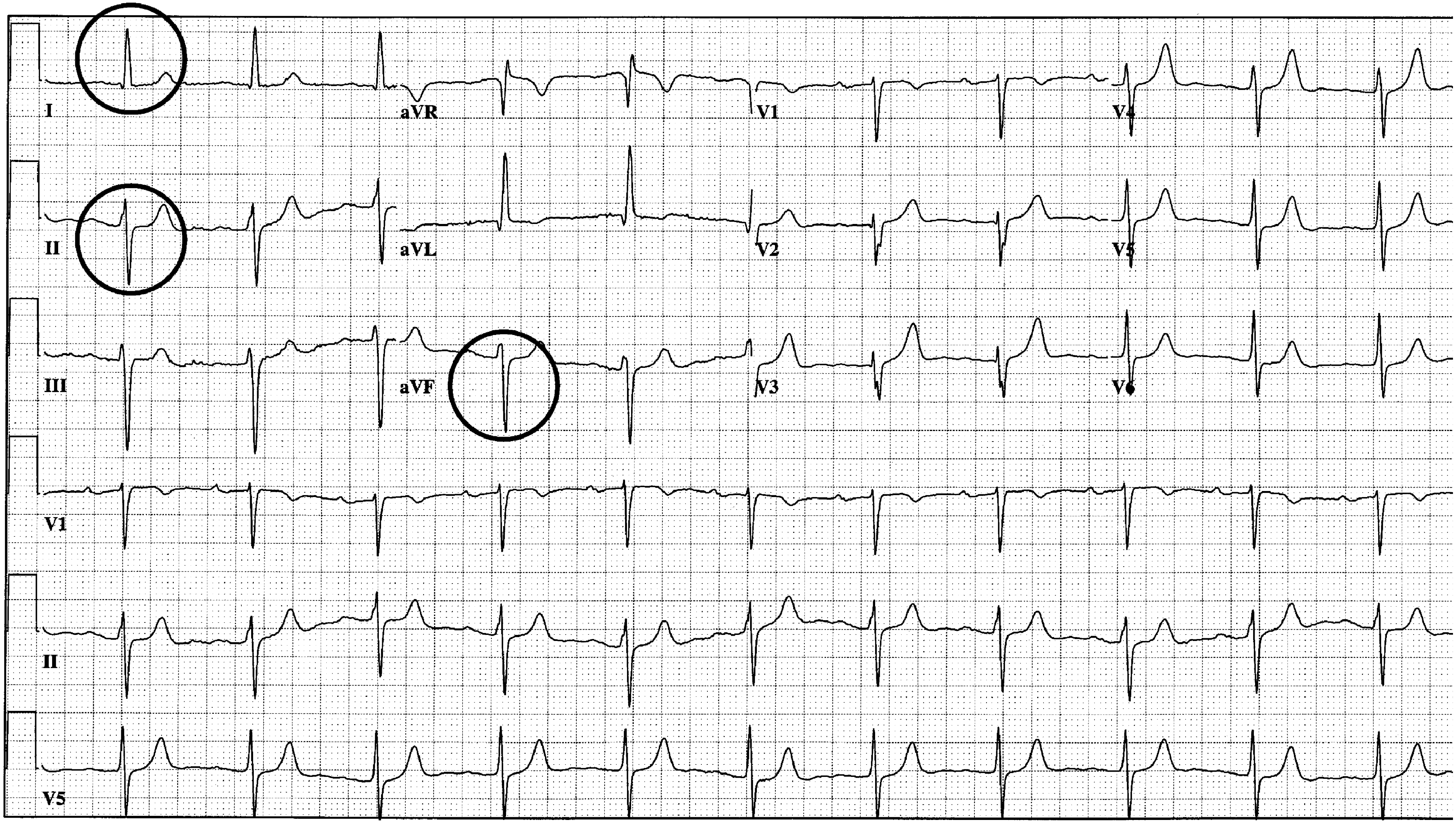
DAY 1-02

Normal QRS axis. Note the upright QRS complex in lead I, downgoing in aVF, and upright in II



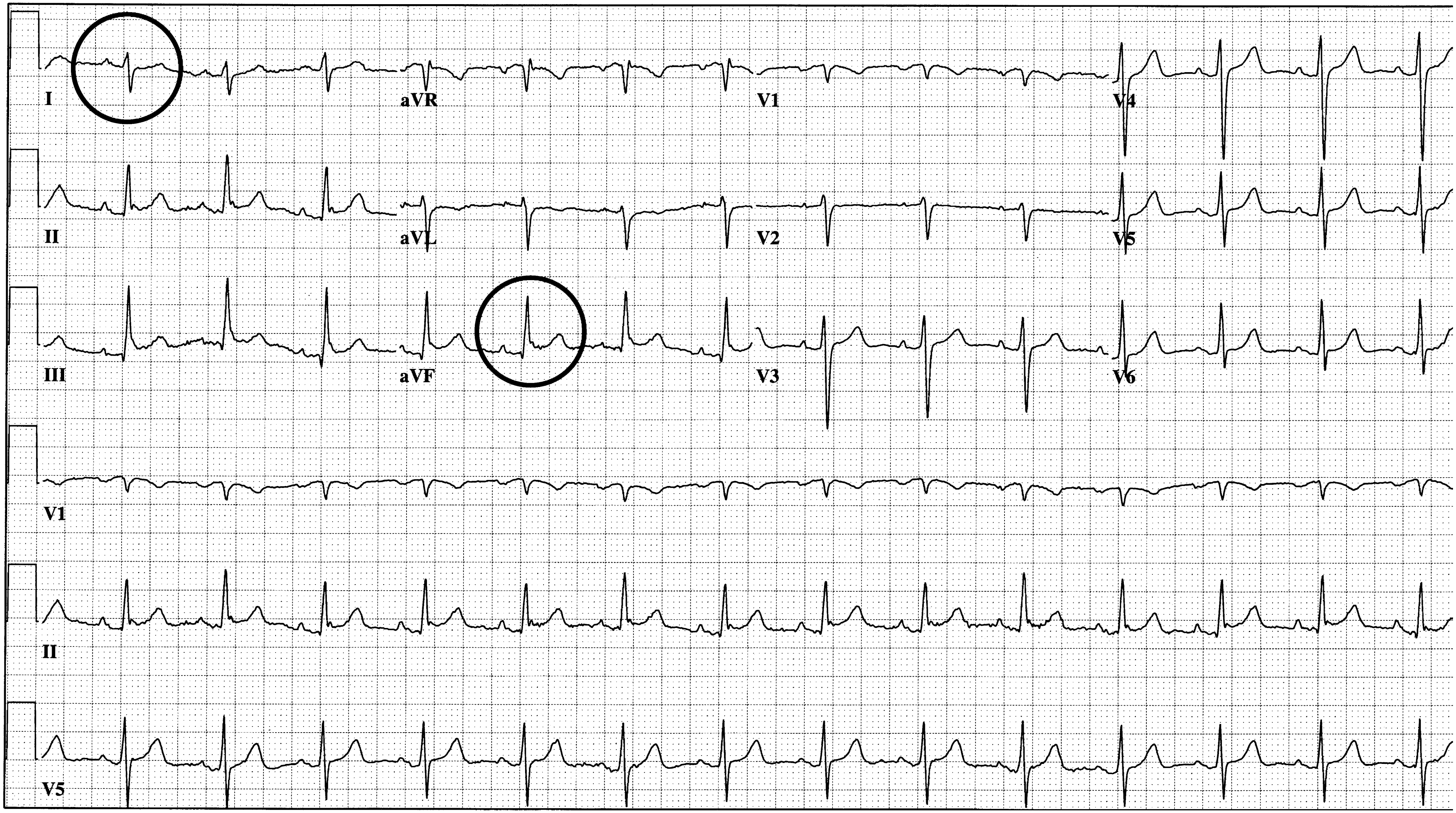
DAY 1-03

Left axis deviation. The QRS complex is upright in Lead I, but downgoing in aVF and II.



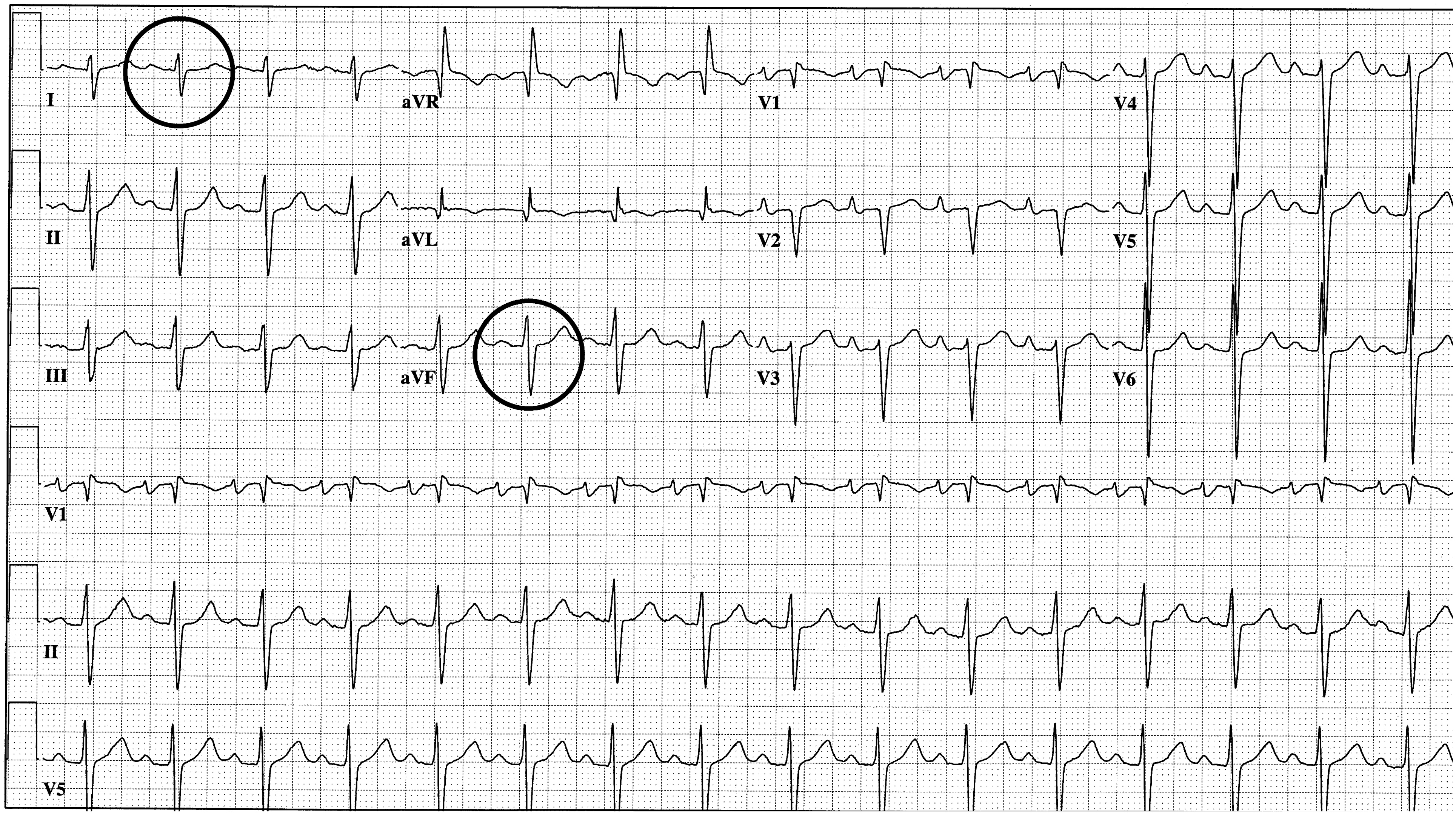
DAY 1-04

Right axis deviation. The QRS complex is downgoing in Lead I, but upright in aVF.

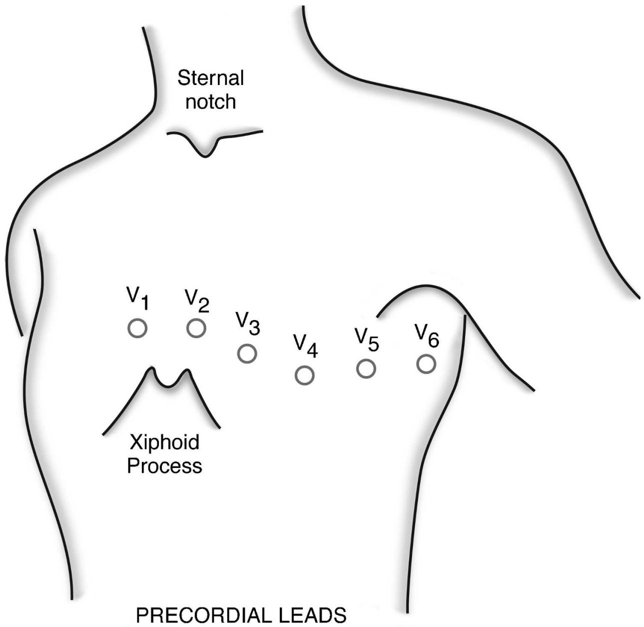


DAY 1-05

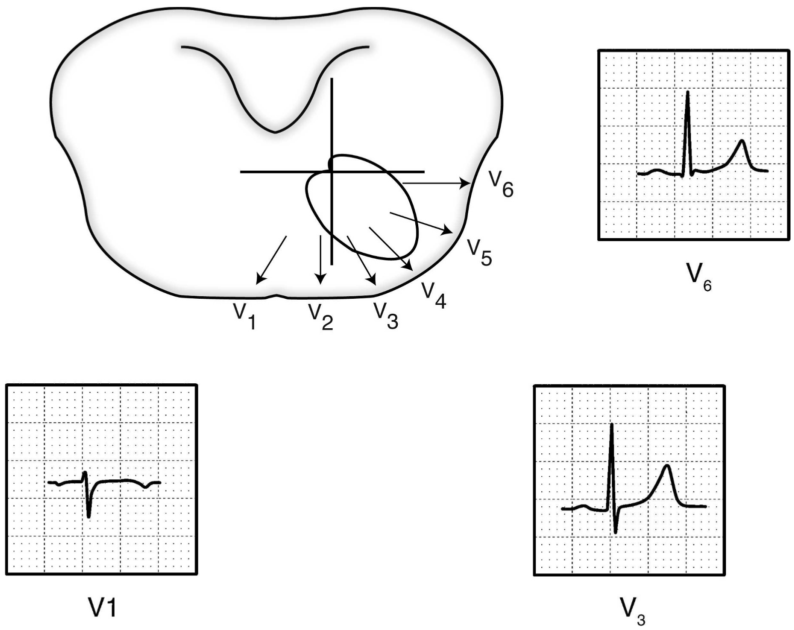
Right superior axis deviation. The QRS complexes are downgoing in Leads I and aVF.



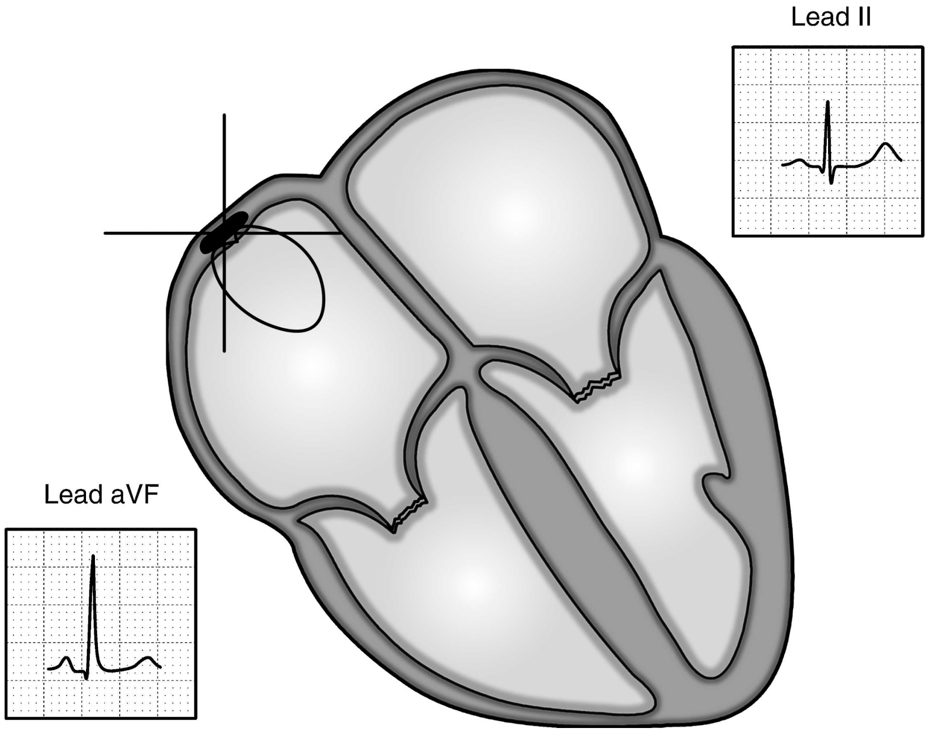
C. The chest leads are constructed similarly from the vector loop viewed in the horizontal plane.



PRECORDIAL LEADS



D. The P wave axis
   1. The normal P wave axis is quite restricted in its range (15°–75°) because of the location of the SA node in the upper right corner of the right atrium.
   2. The P wave should obviously be upright in Leads I and aVF.



VI. Determining heart rate

A. If the rhythm is regular, the rate can be determined by the distance between complexes.

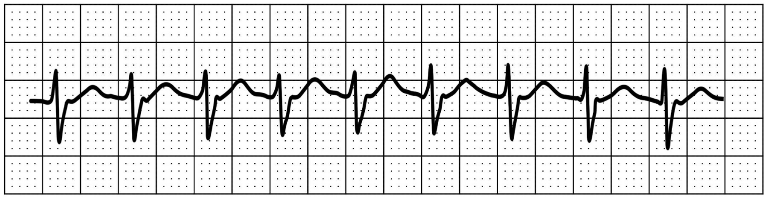
B. If the rhythm is irregular, the rate can be determined by counting the number of beats in 6 sec and multiplying by 10.

VII. Sinus rhythm

A. Sinus rhythm is defined as:
   1. Regularly recurring P waves of the same morphology
   2. A normal P wave axis
   3. A rate between 60 and 100 beats/min

B. In addition, if each P wave is followed by a QRS complex, then there is normal sinus rhythm.

1 complex every major division = rate of 300 beats/min



1 complex every 2 major divisions = rate of 150 beats/min

1 complex every 3 major divisions = rate of 100 beats/min

1 complex every 4 major divisions = rate of 100 beats/min

1 complex every 5 major divisions = rate of 60 beats/min

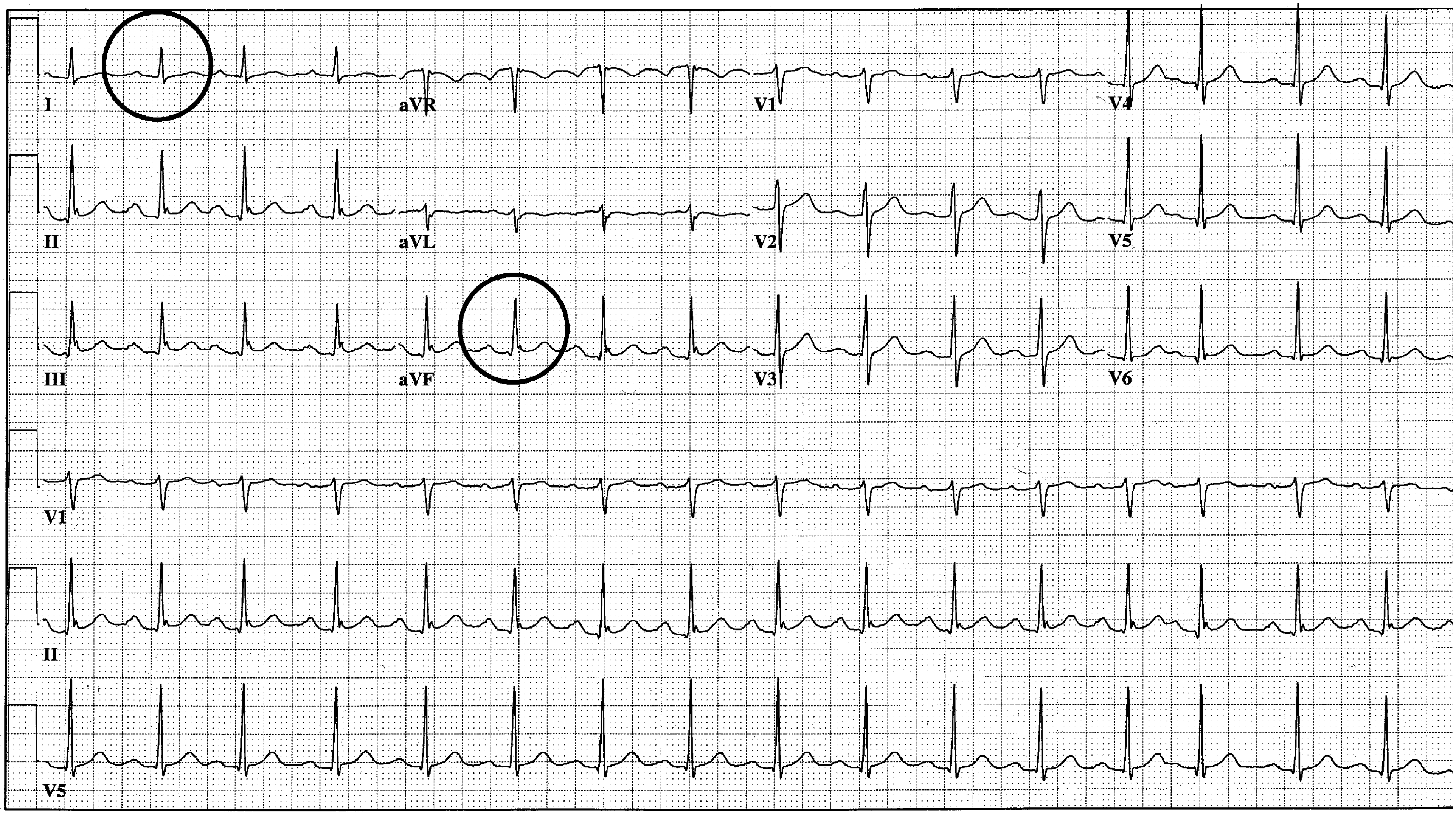
1 complex every 6 major divisions = rate of 50 beats/min

If the rhythm is irregular, the rate can be determined by counting the number of beats in 6 seconds and multiplying by 10 (in this example, there are 9 beats in 6 seconds for a rate of 90)

DAY 1-06

Sinus rhythm, as indicated by:

1. Recurrent P waves of the same morphology
2. An appropriate P wave axis (upright in Leads I and aVF)
3. A rate between 60 and 100



VIII. Systematic approach to ECG interpretation

A. Rate (may be different, e.g., atrial flutter with 4:1 AV block)
   1. Supraventricular
   2. Ventricular

B. Rhythm (may be different, e.g., sinus rhythm and ventricular tachycardia)
   1. Supraventricular
   2. Ventricular

C. P wave morphology (e.g., right or left atrial abnormalities)

D. PR interval

E. QRS complex
   1. Axis
   2. Voltage [e.g., in left ventricular hypertrophy (LVH), right ventricular hypertrophy (RVH), or low voltage]
   3. Duration [e.g., with right bundle branch block [RBBB], left bundle branch block (LBBB), or fascicular blocks]
   4. Morphology (e.g., the presence of Q waves or a tall R wave in V_1)

F. ST segment

G. T wave

H. QT interval

I. U wave

IX. Normal values

Normal Values

	AXIS	INTERVAL
P wave	15° to 75°	—
PR interval	—	120–200 msec
QRS complex	–30° to +90°	80–105 msec
T wave	–30° to +90°	—
QT interval	—	<1/2 the R-R interval

Sample Tracings
ECG 1

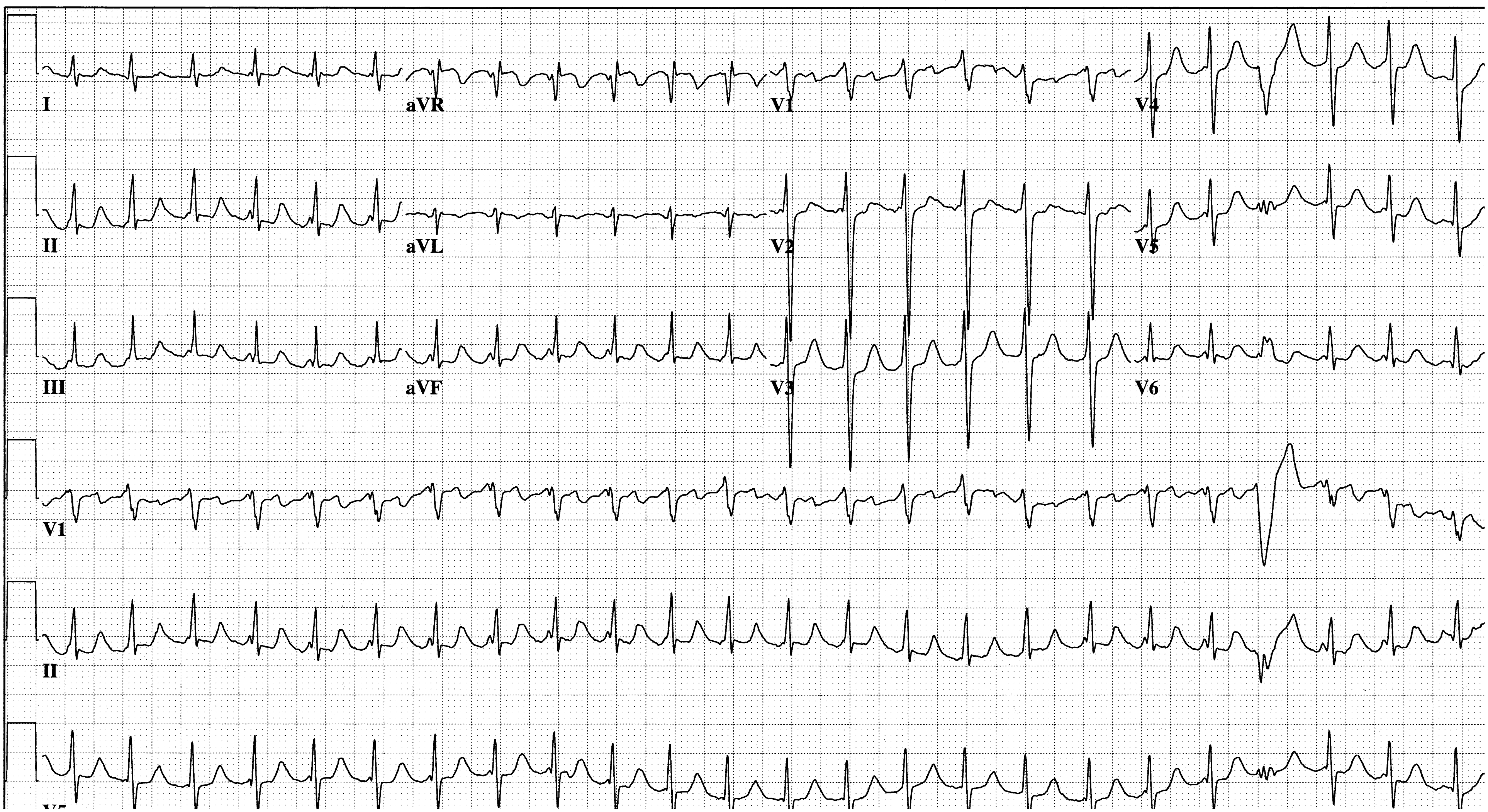
Atrial rate: ____________ QRS complex: ST segment: ____________

Ventricular rate: ____________ Axis: ____________ T wave: ____________

Rhythm: ____________ Duration: ____________ QT interval: ____________

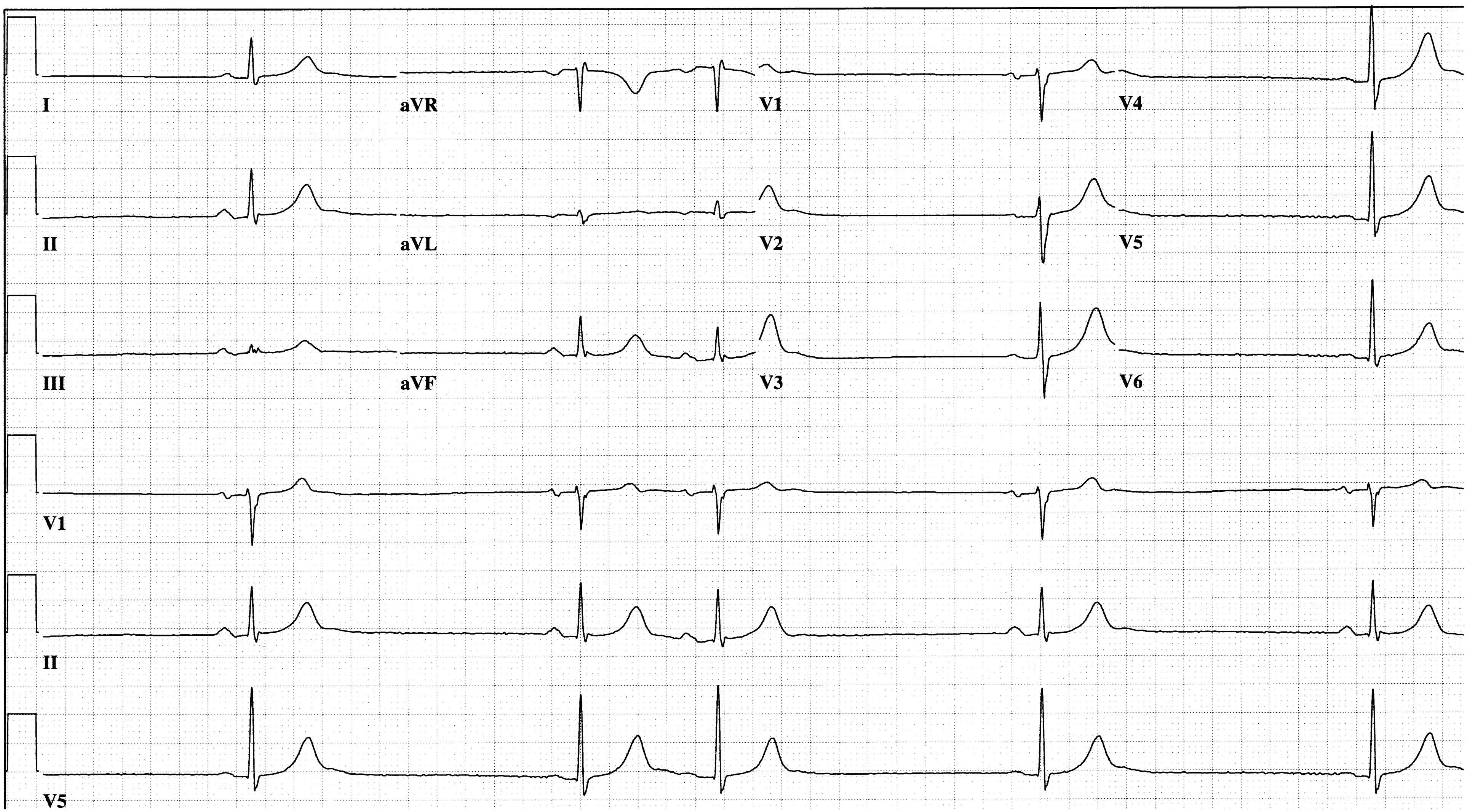
P wave: ____________ Voltage: ____________ U wave: ____________

PR interval: ____________ Morphology: ____________ Diagnosis: ____________



ECG 2

Atrial rate:	QRS complex:	ST segment:
Ventricular rate:	Axis:	T wave:
Rhythm:	Duration:	QT interval:
P wave:	Voltage:	U wave:
PR interval:	Morphology:	Diagnosis:



ECG 3

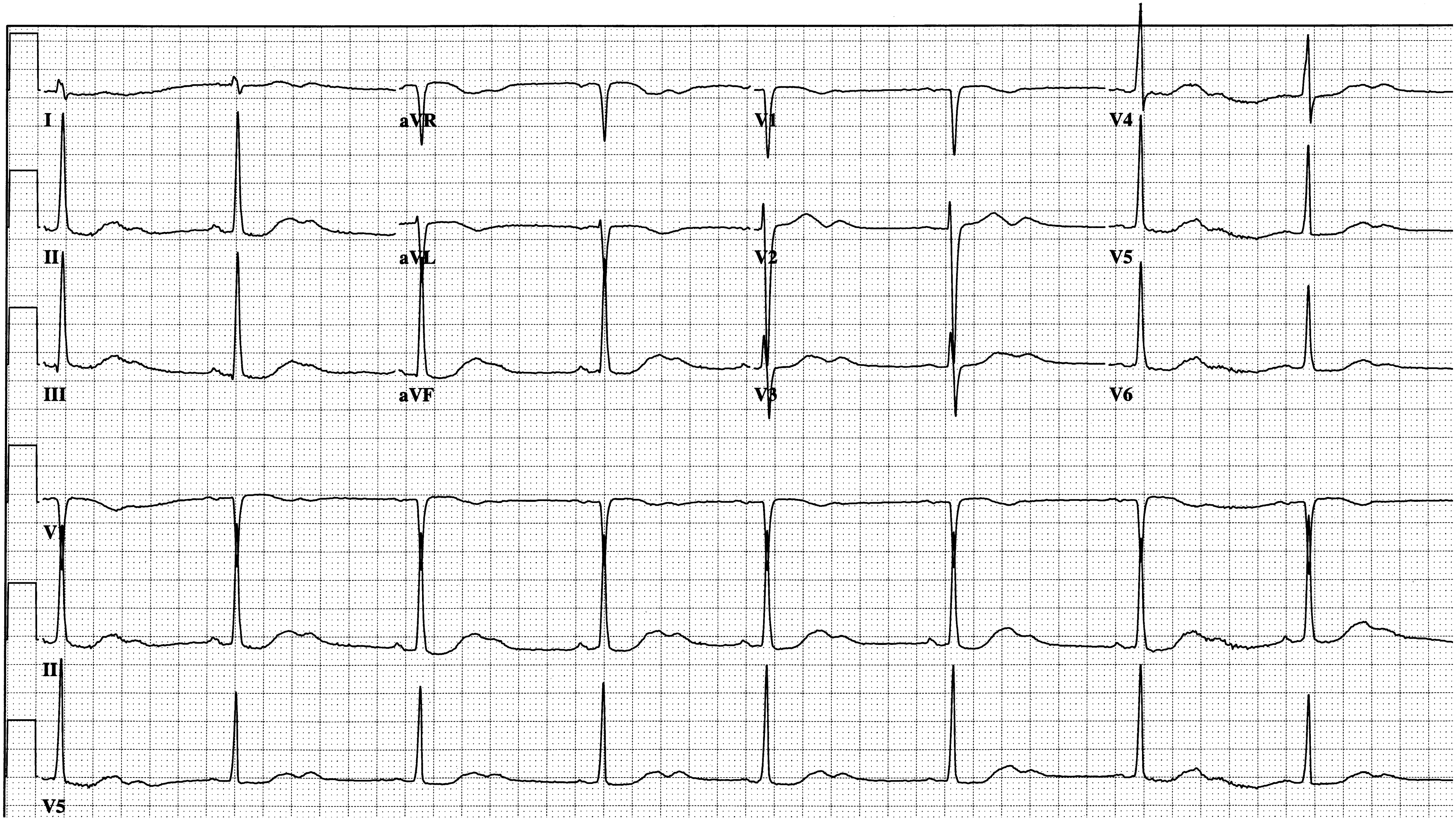
Atrial rate: ________________ QRS complex: ST segment: ________________

Ventricular rate: ________________ Axis: ________________ T wave: ________________

Rhythm: ________________ Duration: ________________ QT interval: ________________

P wave: ________________ Voltage: ________________ U wave: ________________

PR interval: ________________ Morphology: ________________ Diagnosis: ________________



ECG 4

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

ST segment: ____________________

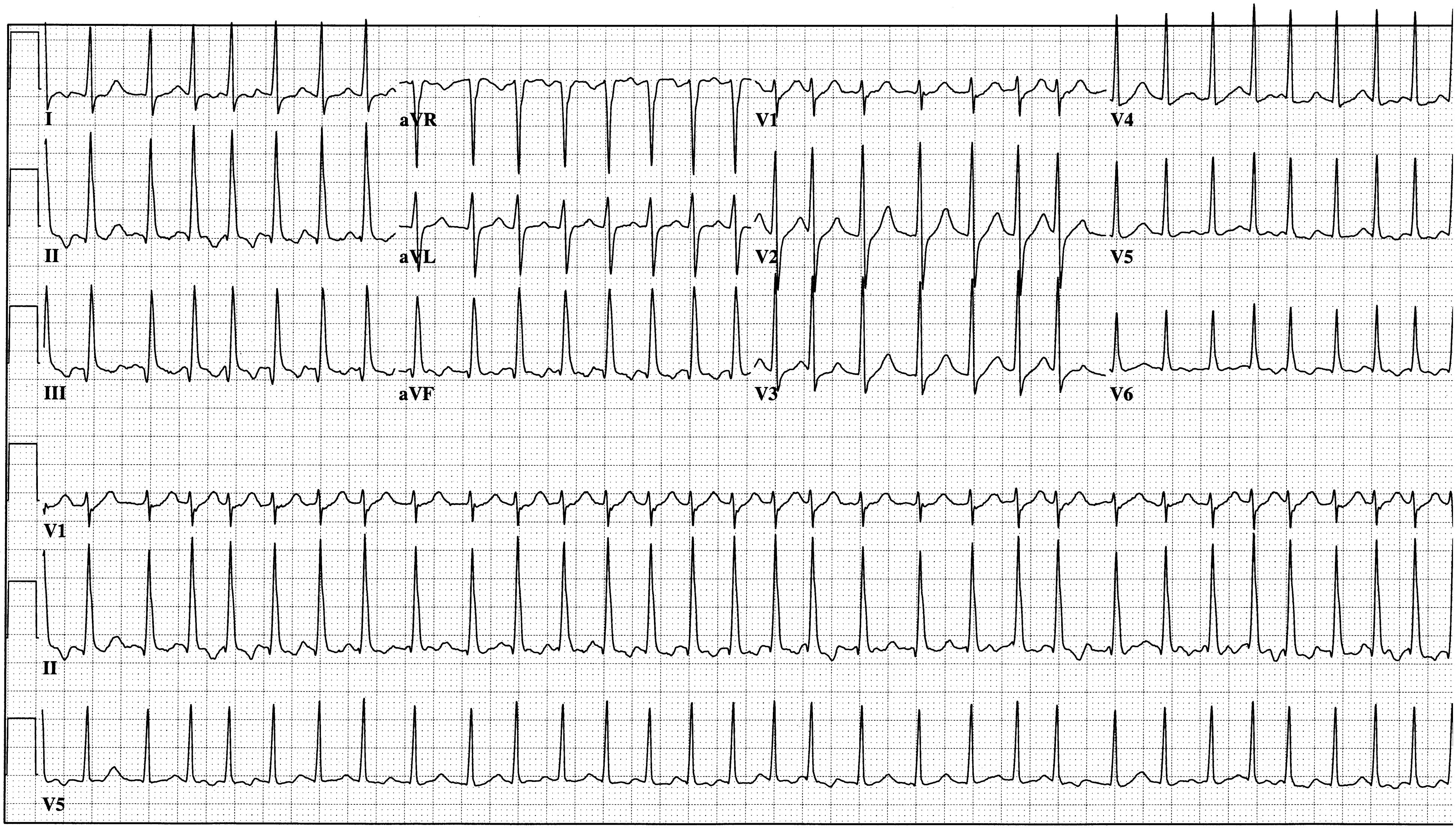
T wave: ____________________

QT interval: ____________________

U wave: ____________________

Diagnosis: ____________________

____



ECG 5

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

T wave: ______________________

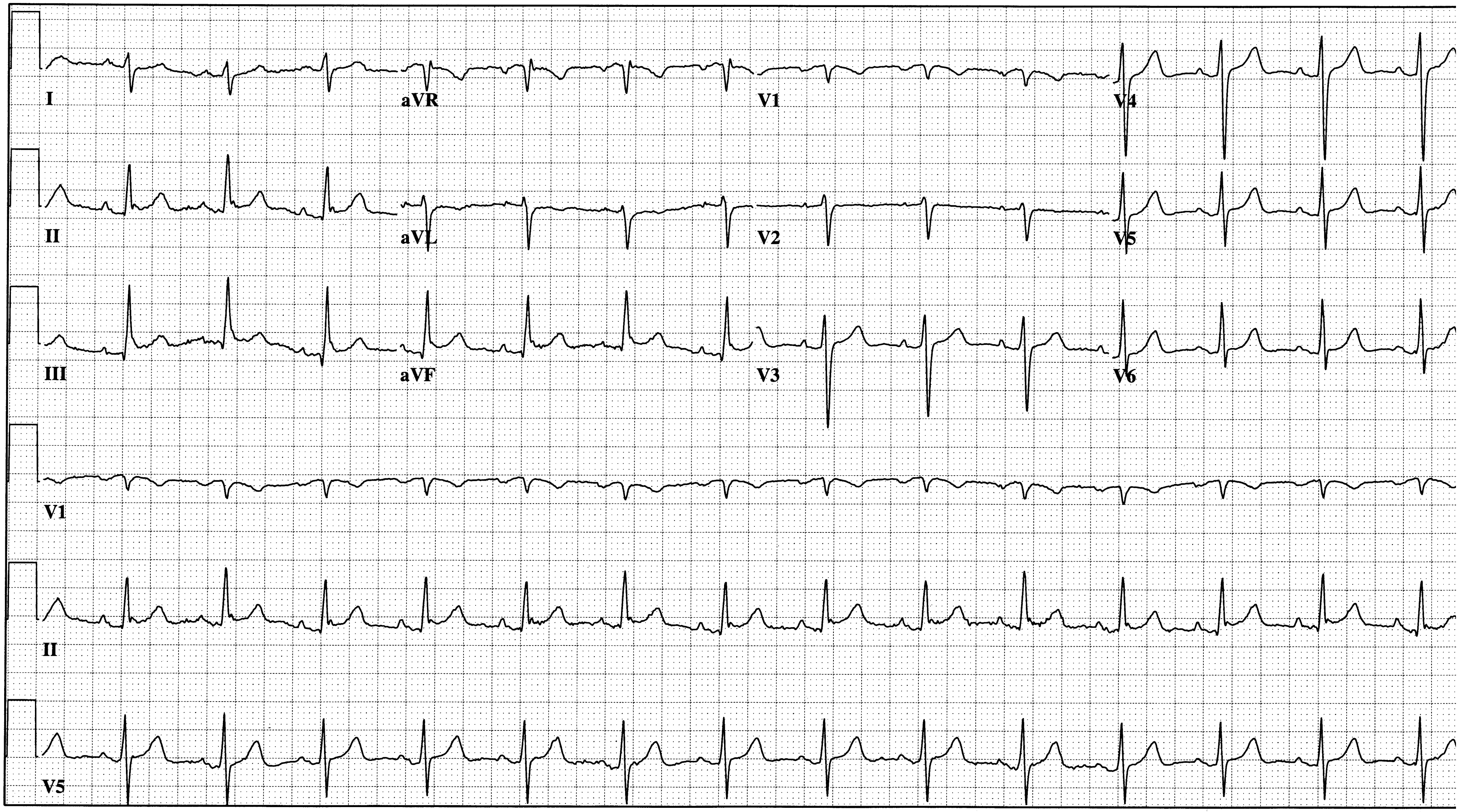
QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

ECG 6

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______
		______



ECG 7

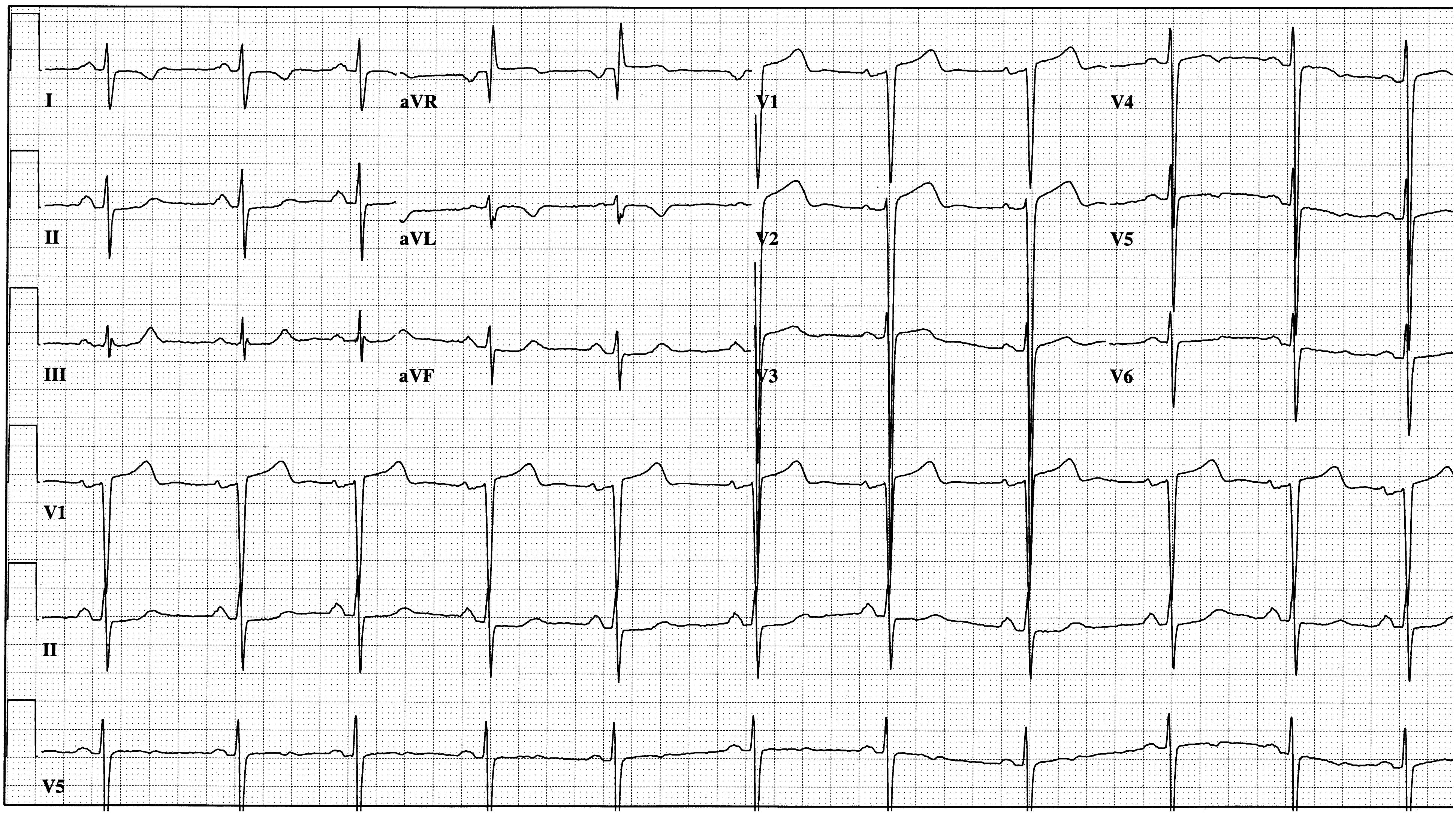
Atrial rate: ____________ QRS complex: ST segment: ____________

Ventricular rate: ____________ Axis: ____________ T wave: ____________

Rhythm: ____________ Duration: ____________ QT interval: ____________

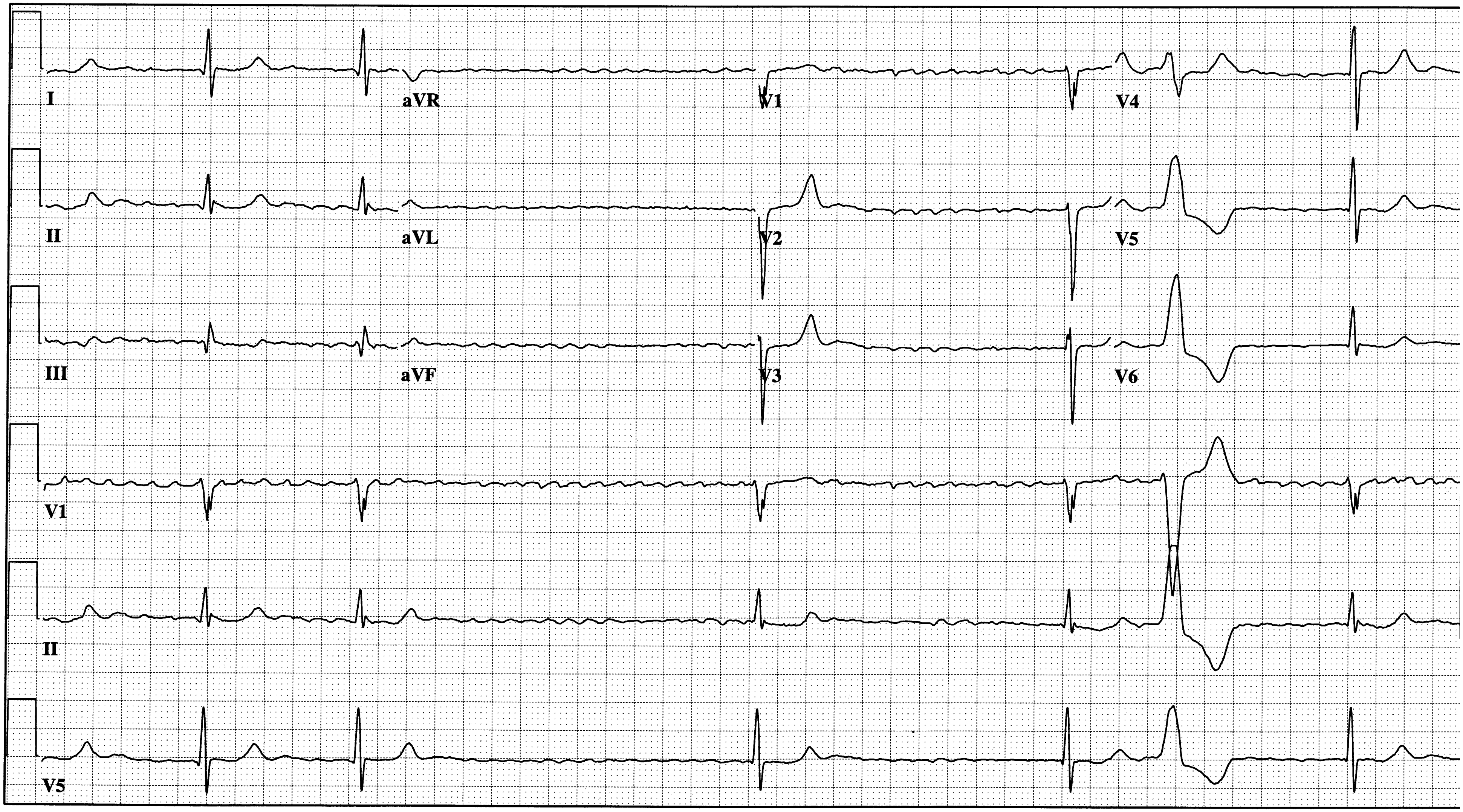
P wave: ____________ Voltage: ____________ U wave: ____________

PR interval: ____________ Morphology: ____________ Diagnosis: ____________



ECG 8

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______
		______



ECG 9

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

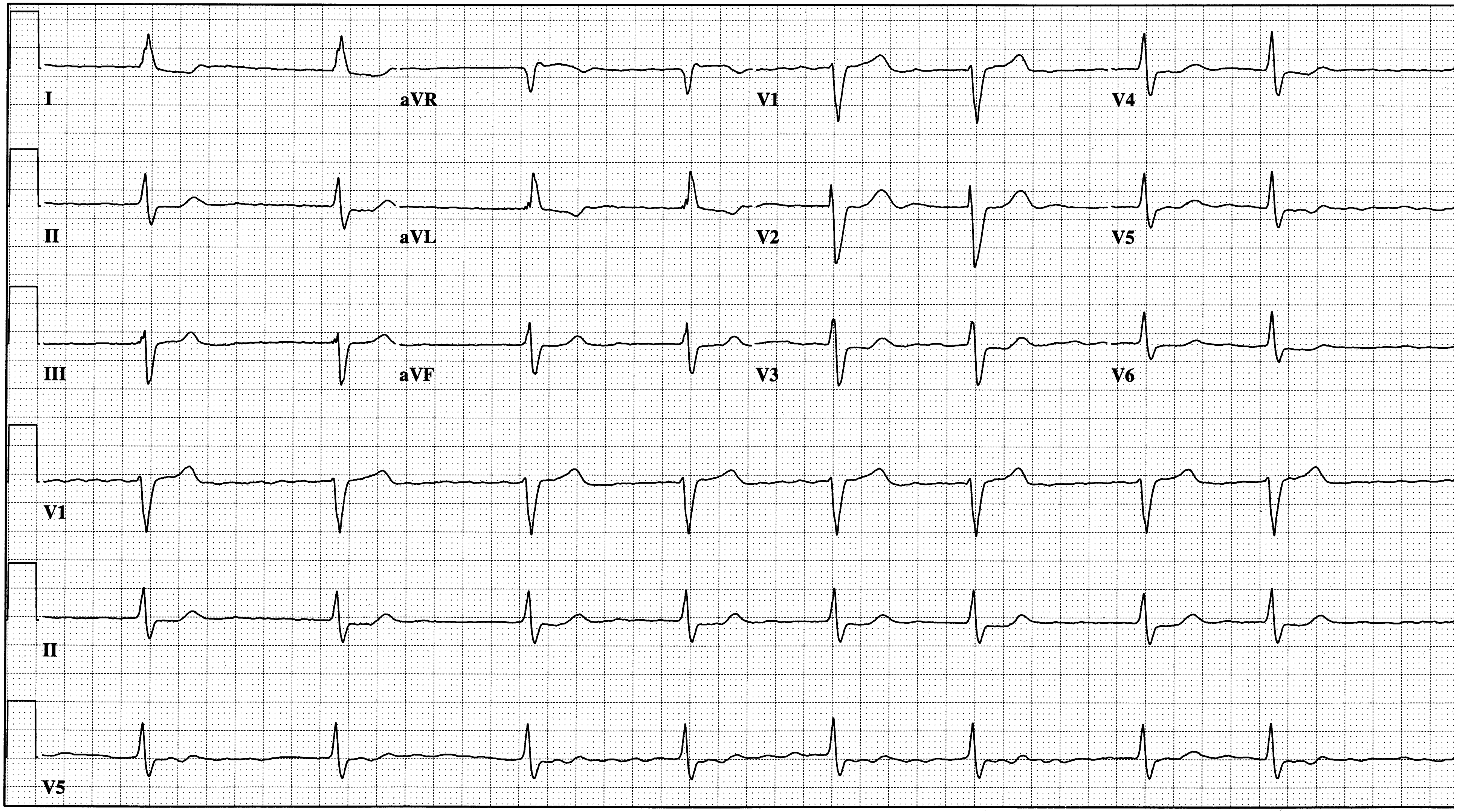
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG 10

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

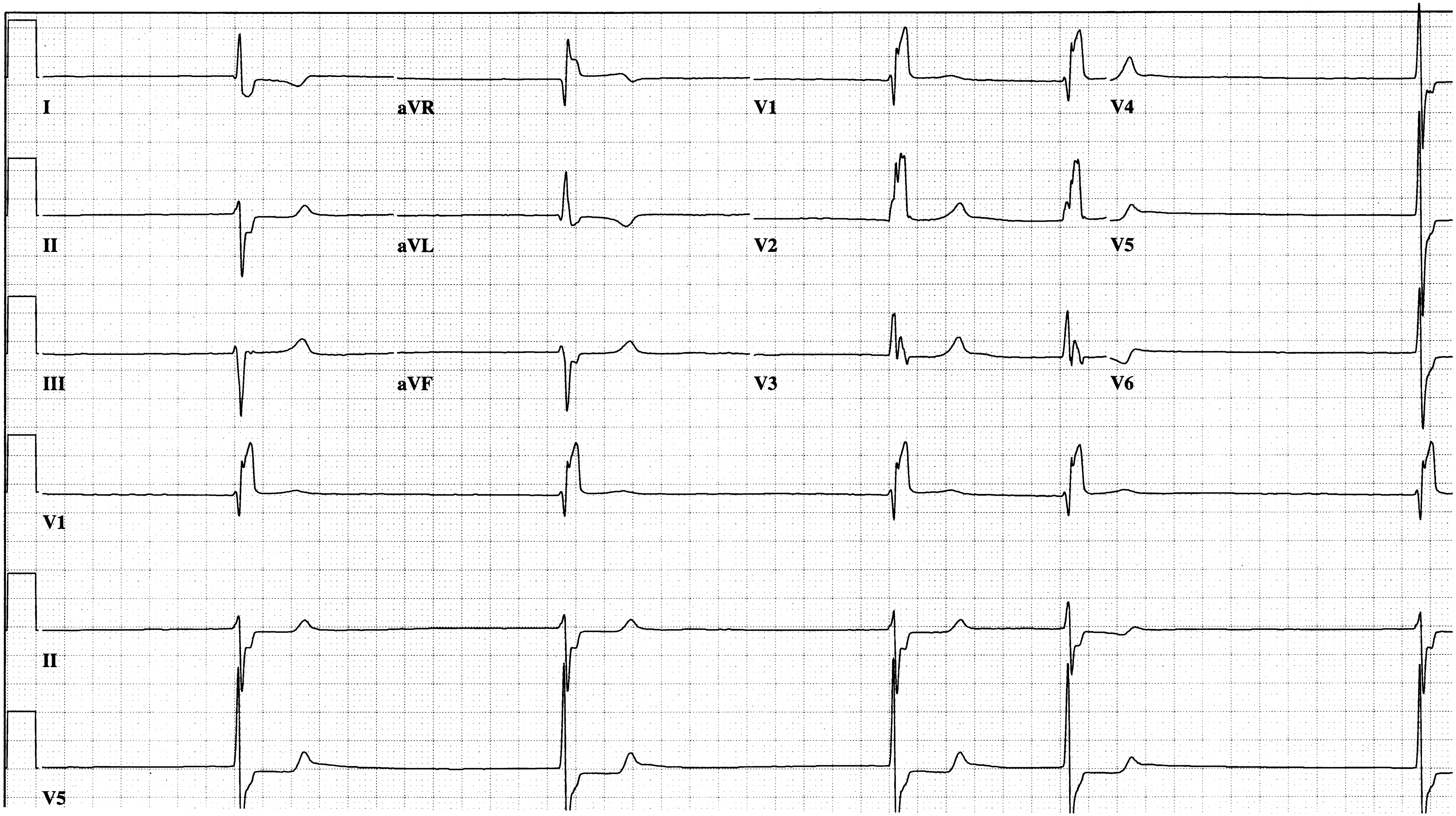
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



The Basics

Interpretations of Sample Tracings

ECG 1

Atrial rate: 290
Ventricular rate: 145
Rhythm: Atrial flutter with 2:1 AV block
P wave:
PR interval:
QRS complex:
  Axis: 80°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment:
T wave:
QT interval: 340 msec
U wave:
Diagnosis: Atrial flutter with 2:1 AV block with an occasional premature ventricular contraction (PVC)

ECG 2

Atrial rate: 30
Ventricular rate: 30
Rhythm: Severe sinus bradycardia
P wave: Normal
PR interval: 240 msec
QRS complex:
  Axis: 60°
  Duration: 80
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 560 msec
U wave:
Diagnosis: Severe sinus bradycardia with sinus arrhythmia and first degree AV block. The mechanism of the bradycardia is not clear.

ECG 3

Atrial rate: 47
Ventricular rate: 47
Rhythm: Sinus bradycardia

P wave: Normal
PR interval: 140 msec
QRS complex:
  Axis: 90°
  Duration: 100 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Nonspecific changes
T wave: Inverted in aVL
QT interval: 500 msec
U wave: Prominent U waves in multiple leads
Diagnosis: Sinus bradycardia with nonspecific S-T changes and prominent U waves

ECG 4

Atrial rate:
Ventricular rate: 187
Rhythm: Atrial fibrillation with rapid ventricular response
P wave:
PR interval:
QRS complex:
  Axis: 60°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Nonspecific changes
T wave: Normal
QT interval: 240 msec
U wave:
Diagnosis: Atrial fibrillation with rapid ventricular response

ECG 5

Atrial rate: 90
Ventricular rate: 90
Rhythm: Sinus rhythm
P wave: Right atrial abnormality
PR interval: 180 msec
QRS complex:
  Axis: Right superior axis deviation
  Duration: 150 msec
  Voltage: Probable RVH by voltage criteria
  Morphology: Previous septal myocardial infarction (MI)
ST segment:
T wave:
QT interval: 400 msec

U wave:
Diagnosis: Sinus rhythm with right atrial abnormality, right superior axis deviation, RBBB, very tall R waves in V_1 suggesting RVH, and Q waves in V_1 and V_2 consistent with a previous septal MI

ECG 6

Atrial rate: 85
Ventricular rate: 85
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: 100°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Mild diffuse ST segment elevation
T wave: Inverted in aVL
QT interval: 340 msec
U wave:
Diagnosis: Sinus rhythm, right axis deviation, and diffuse ST segment elevation presumably representing early repolarization

ECG 7

Atrial rate: 65
Ventricular rate: 65
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: Right superior axis deviation
  Duration: 90 msec
  Voltage: Normal
  Morphology: Deep persistent S waves across the pericardium
ST segment: ST segment elevation V_1 to V_3
T wave: T wave inversion in I, aVL, V_4, and V_5
QT interval: 400 msec
U wave:
Diagnosis: Sinus rhythm with right superior axis deviation, persistent deep S waves in the precordial leads, and nonspecific ST-T wave changes

ECG 8

Atrial rate:
Ventricular rate: 37
Rhythm: Atrial fibrillation
P wave:
PR interval:
QRS complex:
  Axis: 45°
  Duration: 100 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Nonspecific changes
T wave: Normal
QT interval: 500 msec
U wave:
Diagnosis: Atrial fibrillation with a slow ventricular response and a single PVC

ECG 9

Atrial rate:
Ventricular rate: 53
Rhythm: Atrial fibrillation
P wave:
PR interval:
QRS complex:
  Axis: −20°
  Duration: 135 msec, nonspecific intraventricular conduction defect (IVCD)
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Nonspecific changes
QT interval: 460 msec
U wave:
Diagnosis: Atrial fibrillation with a slow ventricular response, a nonspecific IVCD, and nonspecific T wave changes

ECG 10

Atrial rate:
Ventricular rate: 28
Rhythm:
P wave:
PR interval:

QRS complex:
Axis: −75°
Duration: 160 msec
Voltage: Normal
Morphology: Normal
ST segment: Normal
T wave: Nonspecific changes
QT interval: 750 msec
U wave:
Diagnosis: Left axis deviation. It is not clear what the rhythm is from this ECG. Atrial fibrillation with a virtually isoelectric baseline and a slow ventricular response is one possibility. Atrial asystole with an irregular junctional or ventricular escape rhythm is a less likely possibility

Day 2

Chamber Abnormalities and Intraventricular Conduction Defects

I. General statements

A. Echocardiography and other newer imaging techniques, not the electrocardiogram (ECG), are the gold standards for assessing chamber size and wall thickness.

B. In general, the sensitivities of the following criteria are moderate (in the range of 50%), and the specificities are very high (> 90%).

II. Right atrial abnormality (Day 2-1)

A. The P wave is pointed in II, III, or aVF, and the amplitude is >2.5 mm (historically referred to as *P pulmonale*).

B. P wave axis is frequently >70°.

III. Left atrial (LA) abnormality

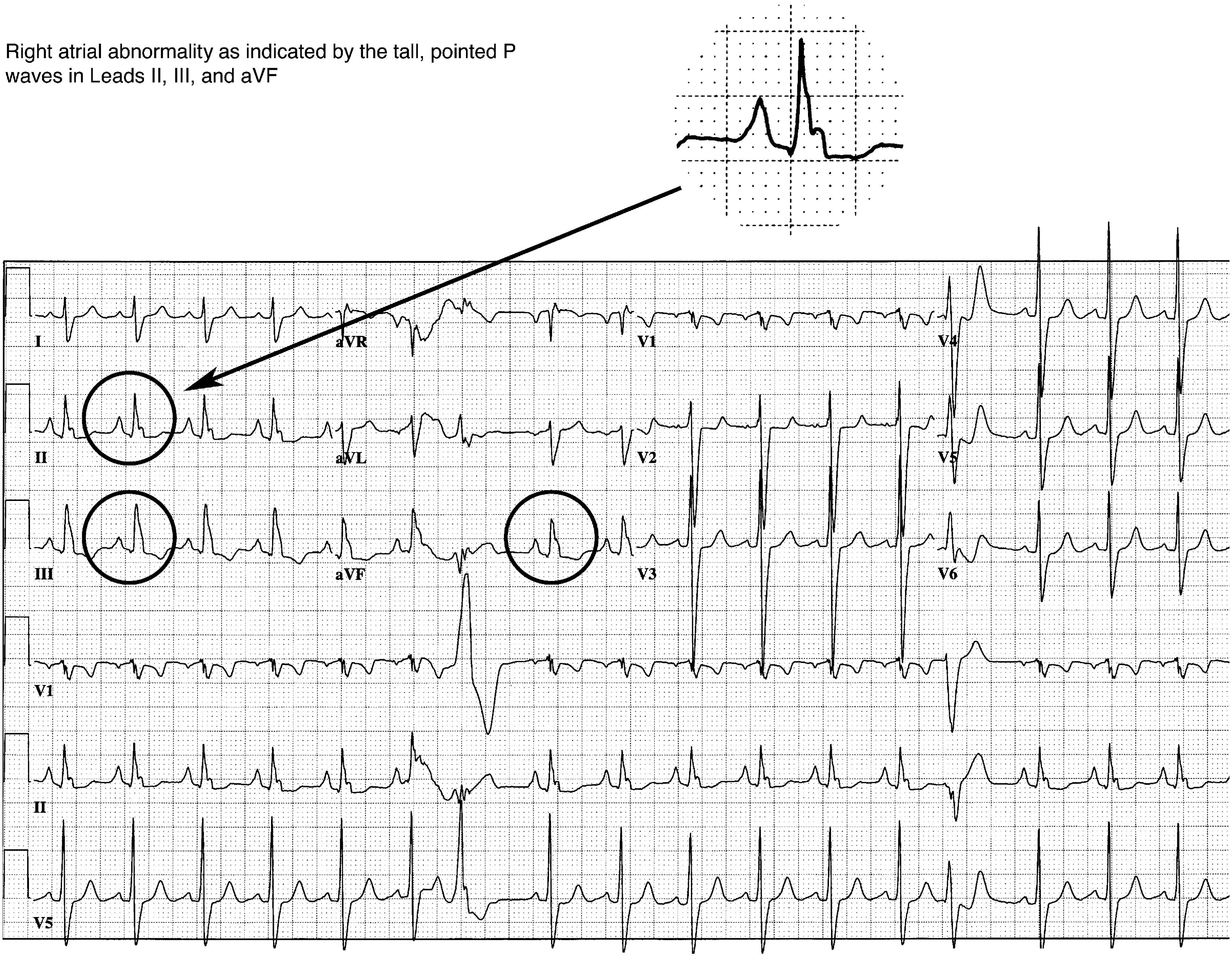
A. In most forms of acquired LA abnormality, the commonest manifestation is a wide (>40 msec) and deep (>1 mm) terminal portion of the P wave in V_1. (Day 2-2)

B. An appearance typical in mitral valvular disease is a "double-humped" P wave, at least 130 msec in duration, in II, III, or aVF (so-called *P mitrale*). (Day 2-3)

IV. Biatrial abnormality—suggested by a combination of tall P waves in II, III, or aVF, and the terminal negativity in V_1. (Day 2-4)

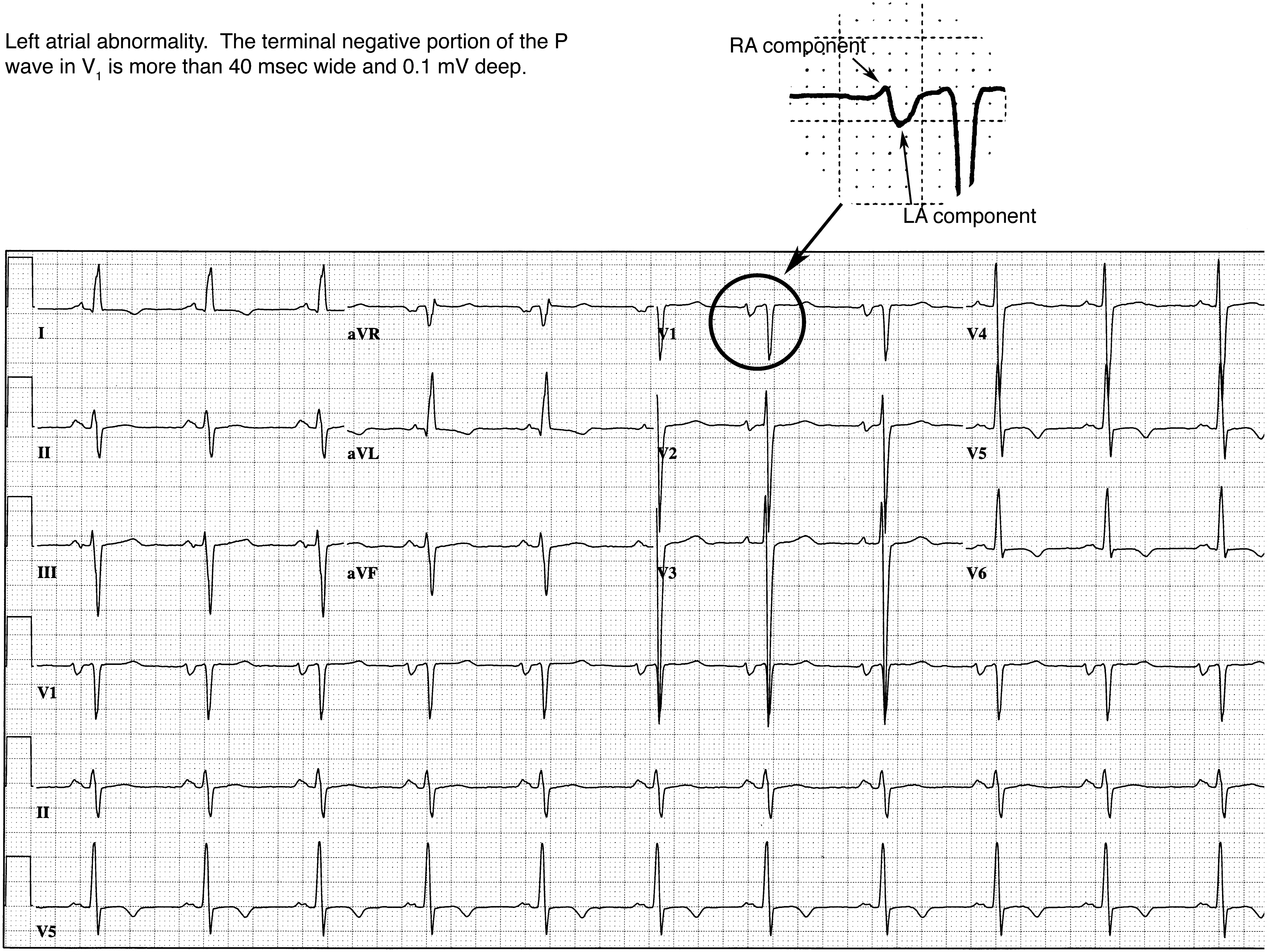
DAY 2-01

Right atrial abnormality as indicated by the tall, pointed P waves in Leads II, III, and aVF



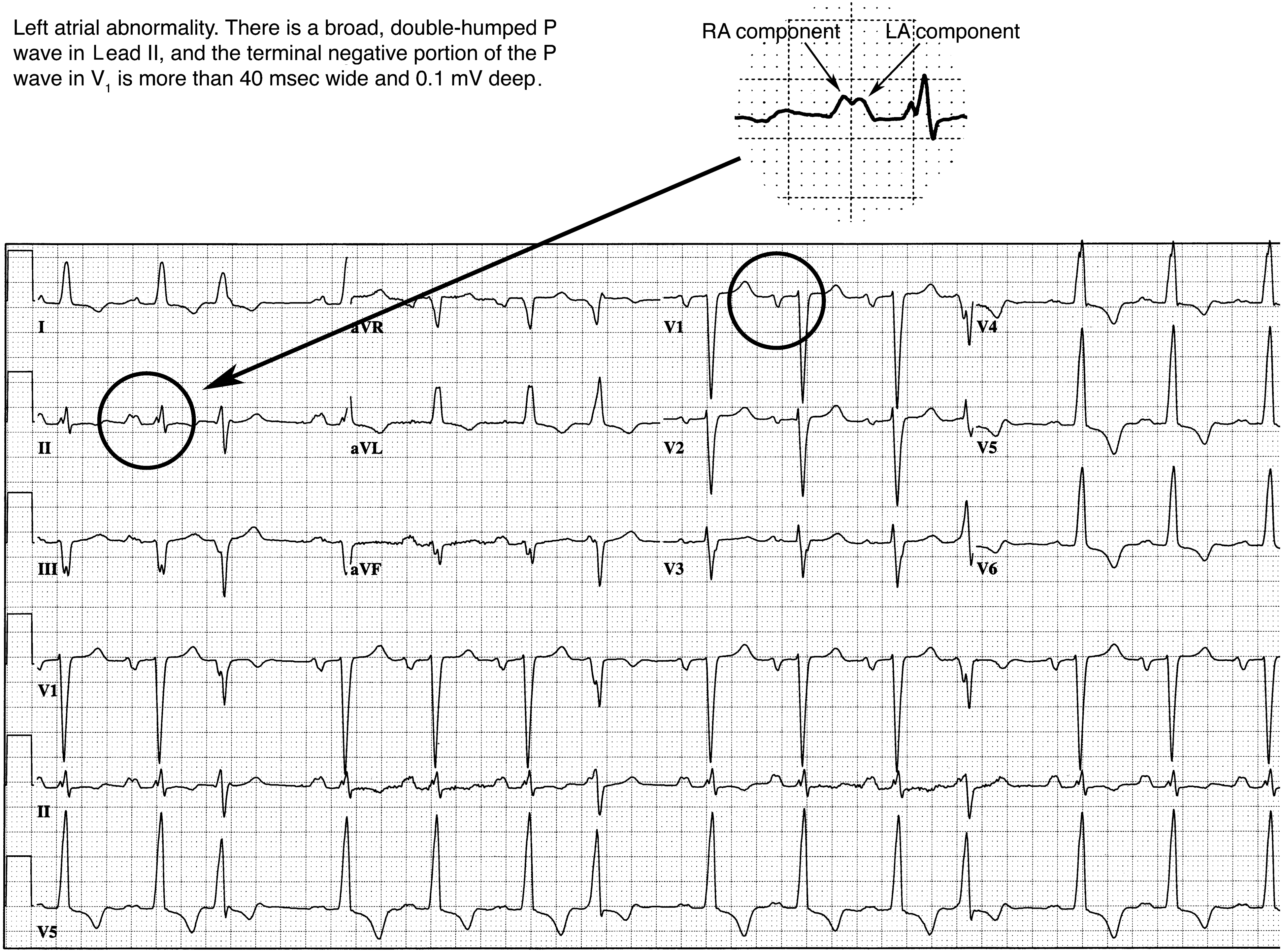
DAY 2-02

Left atrial abnormality. The terminal negative portion of the P wave in V_1 is more than 40 msec wide and 0.1 mV deep.



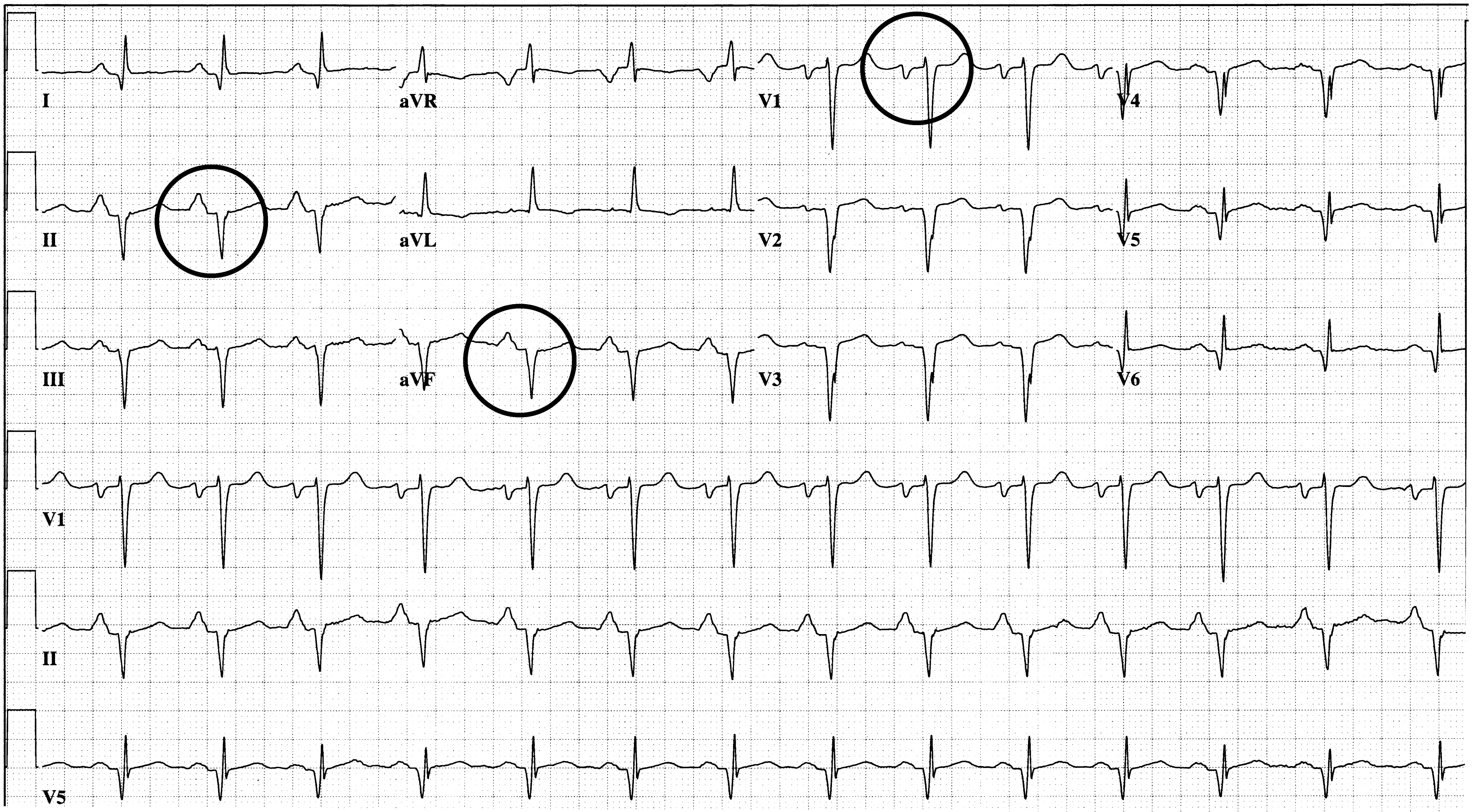
DAY 2-03

Left atrial abnormality. There is a broad, double-humped P wave in Lead II, and the terminal negative portion of the P wave in V_1 is more than 40 msec wide and 0.1 mV deep.



DAY 2-04

Right and left atrial abnormality. There are tall, pointed P waves in Leads II and aVF, and the terminal negative portion of the P wave in V_1 is more than 40 msec wide and 0.1 mV deep.



V. Right ventricular hypertrophy (RVH) (Day 2-5)

A. RVH is *suggested* by all the following:
1. Right axis deviation
2. A tall R wave in V_1 ($\geq$7 mm)
3. R wave in V_1 + S wave in V_6 $\geq$10 mm
4. R/S ratio in $V_1 \geq 1$
5. Incomplete RBBB pattern
6. Right atrial abnormality
7. S > R in V_6

B. The diagnosis of RVH requires exclusion of the other causes of a tall R wave in V_1 (see Day 9).

C. RVH in patients with acquired pulmonary disease tends to present in a different form: (Day 2-6)
1. Deep S waves are present across the precordium.
2. The R wave transition across the precordium is delayed.
3. Right axis deviation and right atrial abnormality are frequently present.
4. Low voltage may be present.

VI. Left ventricular hypertrophy (LVH)

A. Precordial leads (any of the following) (Day 2-7)
1. S wave in V_1 + R wave in V_5 or V_6 > 35 mm in adults (> 30 years)
2. R wave in V_5 or V_6 > 26 mm

B. Limb leads (any of the following) (Day 2-8)
1. R wave in I > 14 mm
2. R wave in aVL > 11 mm

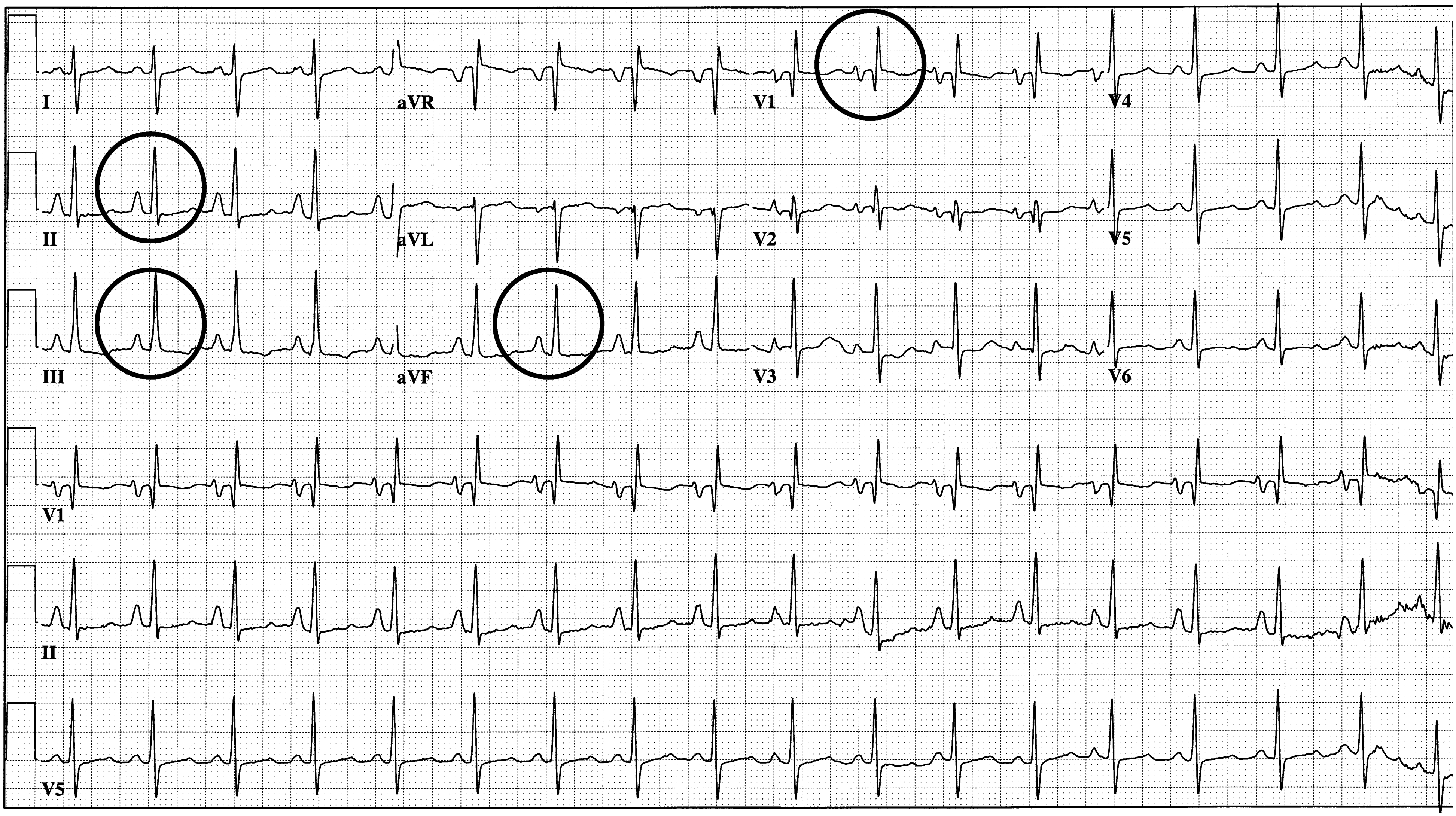
C. LVH is frequently accompanied by ST segment and T wave abnormalities, sometimes referred to as a "strain" pattern, but more appropriately as "repolarization" abnormalities.

VII. Low voltage (Day 2-9)

A. Definition
1. No QRS complex with an absolute value $\geq$ 0.1 mv (10 mm)
2. Or, no limb lead QRS $\geq$ 0.05 mv (5 mm) (so-called low voltage in the limb leads)

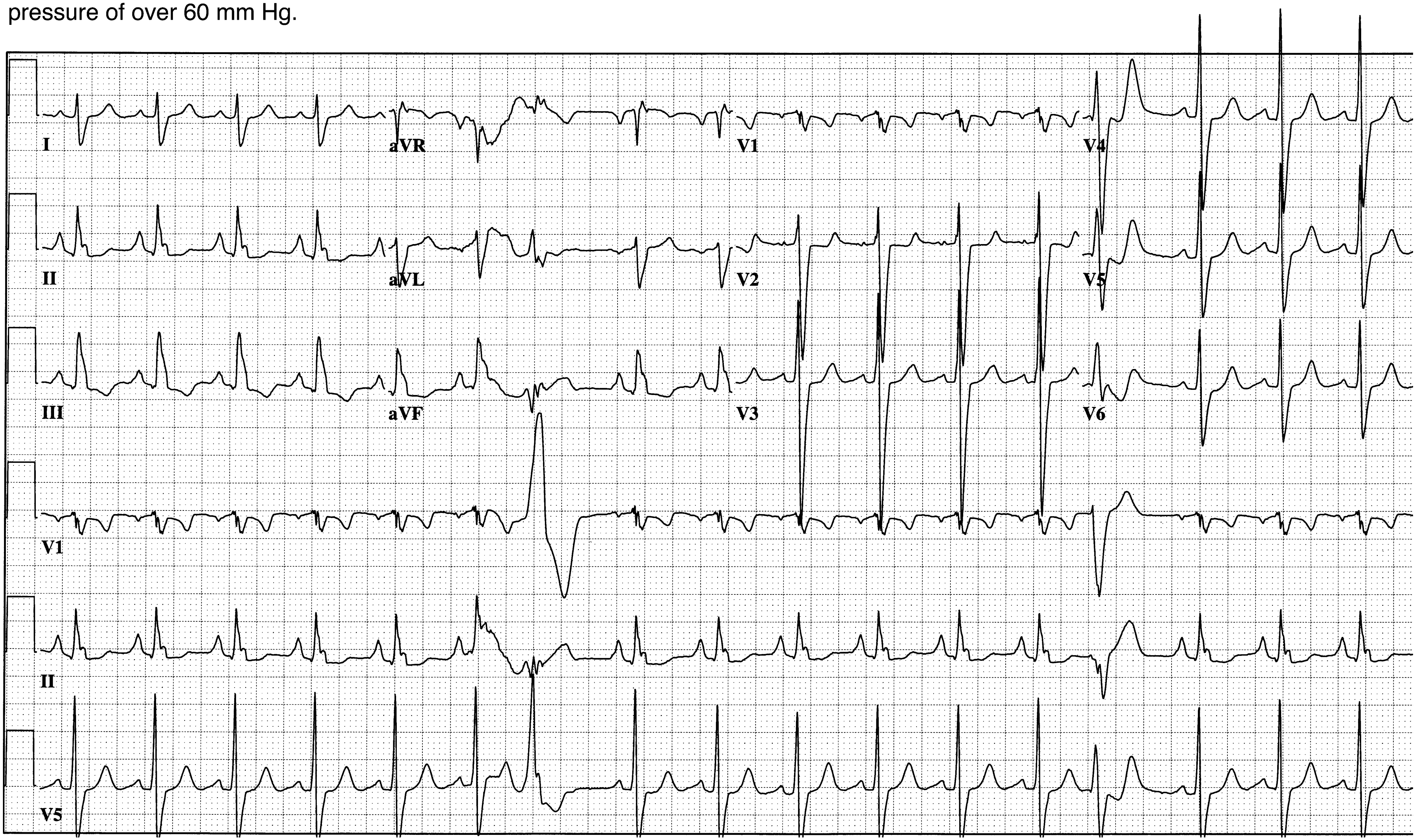
DAY 2-05

RVH as evidenced by right axis deviation, right atrial abnormality, and tall R waves in V_1. This woman had primary pulmonary hypertension with a pulmonary artery systolic pressure of 93 mm Hg and moderate RVH by echo.



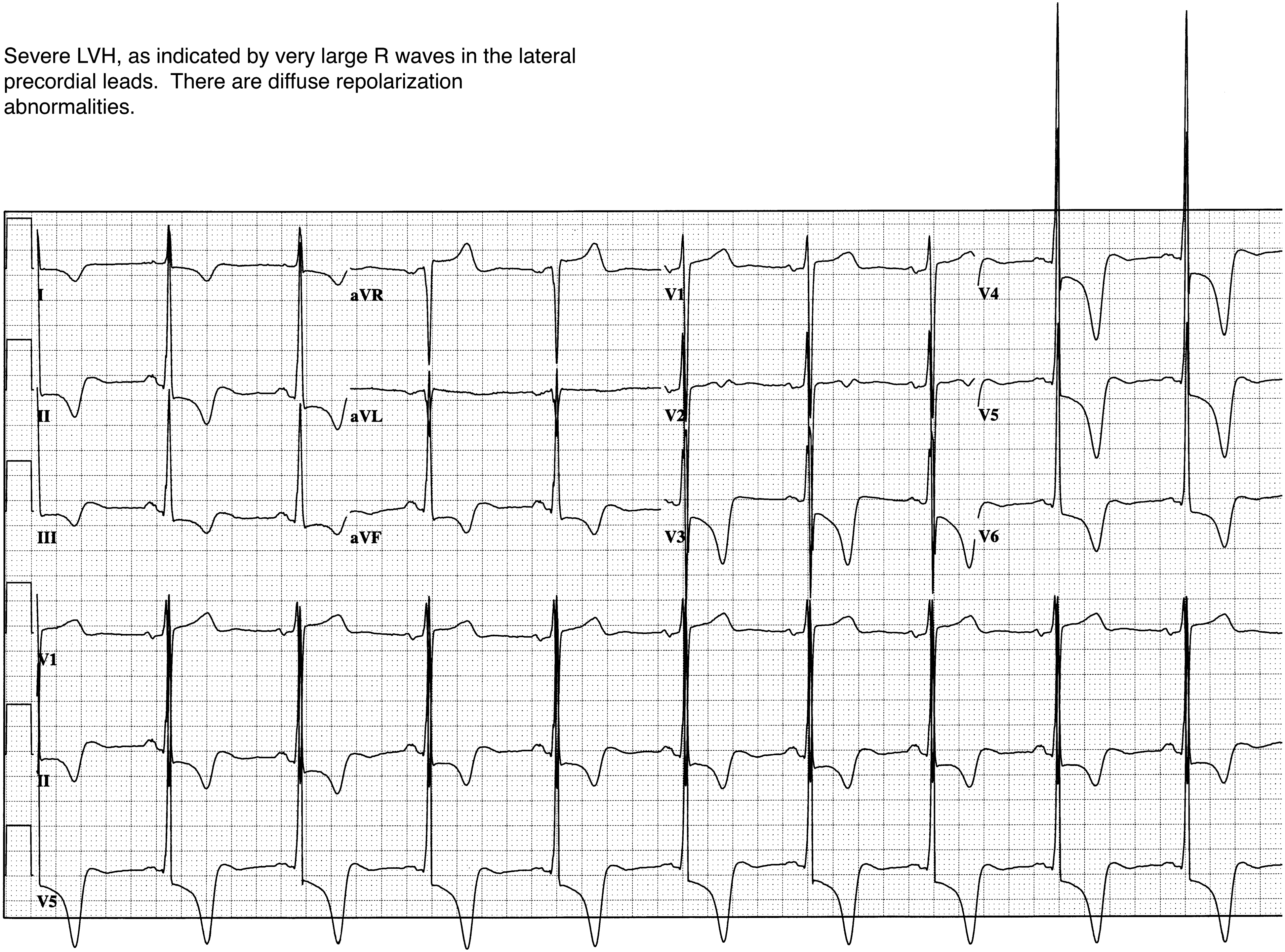
DAY 2-06

Chronic pulmonary disease pattern. There is right axis deviation, right atrial abnormality, and deep S waves across the precordium. This patient had severe COPD clinically, and echo showed severe RVH and a pulmonary systolic pressure of over 60 mm Hg.



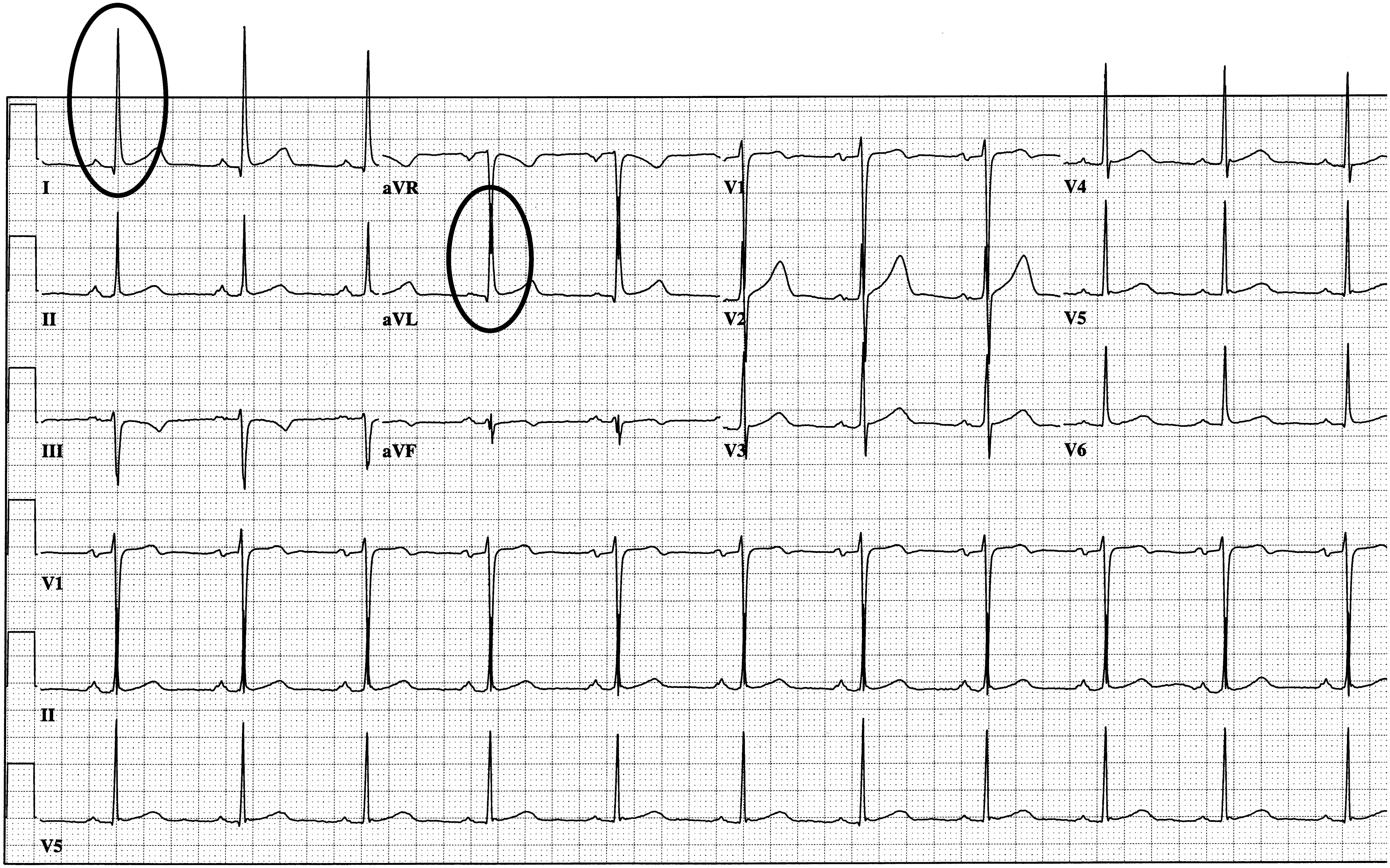
DAY 2-07

Severe LVH, as indicated by very large R waves in the lateral precordial leads. There are diffuse repolarization abnormalities.



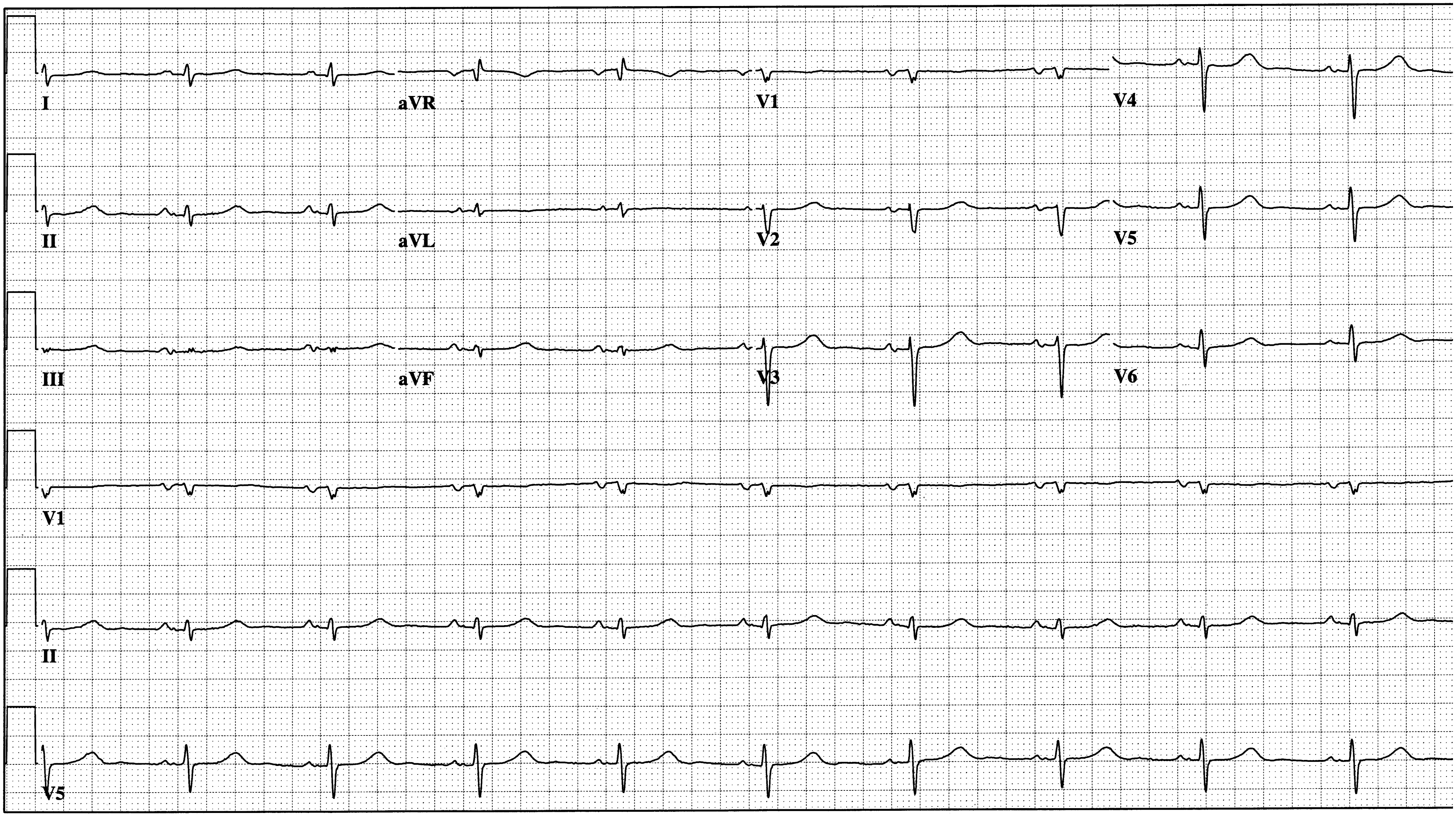
DAY 2-08

LVH, as indicated by the tall R waves in Leads I and aVL



DAY 2-09

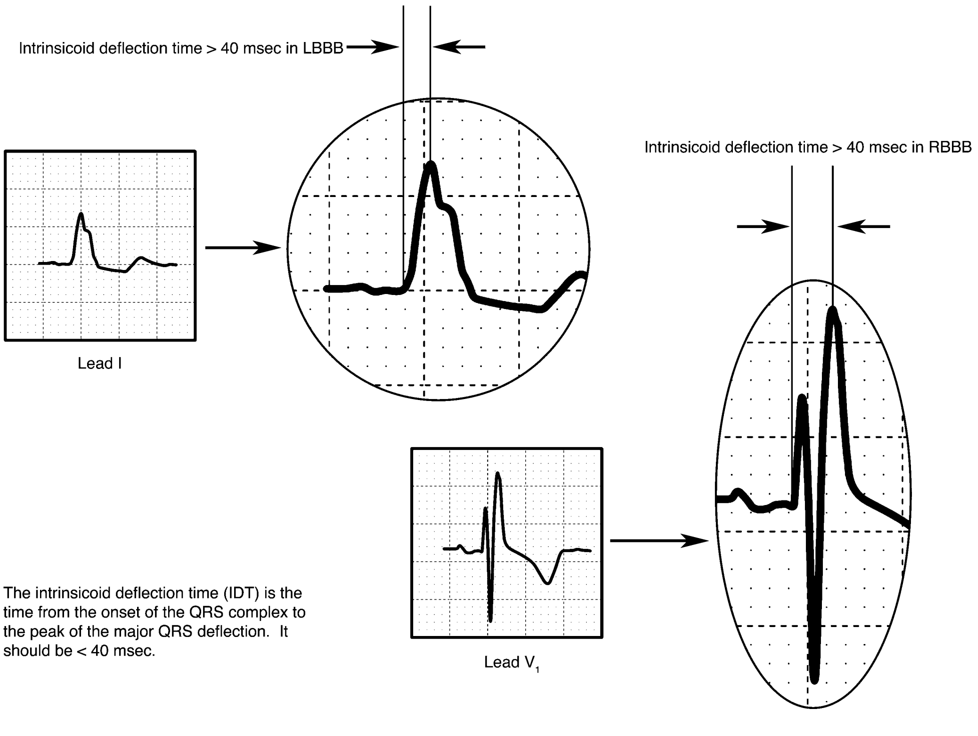
Low voltage in a patient with severe COPD



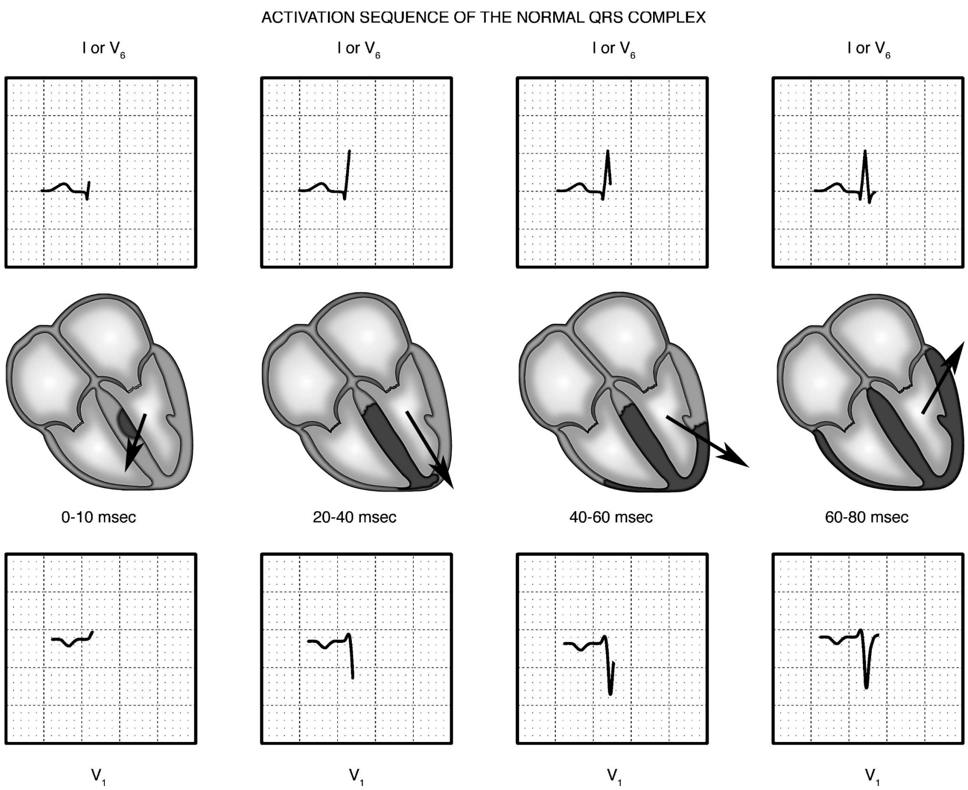
B. Causes
   1. Decreased voltage production by the myocardium
      a. Restrictive cardiomyopathies (amyloidosis, sarcoidosis, etc.)
      b. Hypothyroidism
   2. Increased impedance between the voltage producing source (the myocardium) and the ECG leads
      a. Fat (obesity)
      b. Air [chronic obstructive pulmonary disease (COPD), tension pneumothorax]
      c. Water (pericardial or pleural effusion, ascites)

VIII. Intraventricular conduction defects (IVCDs)

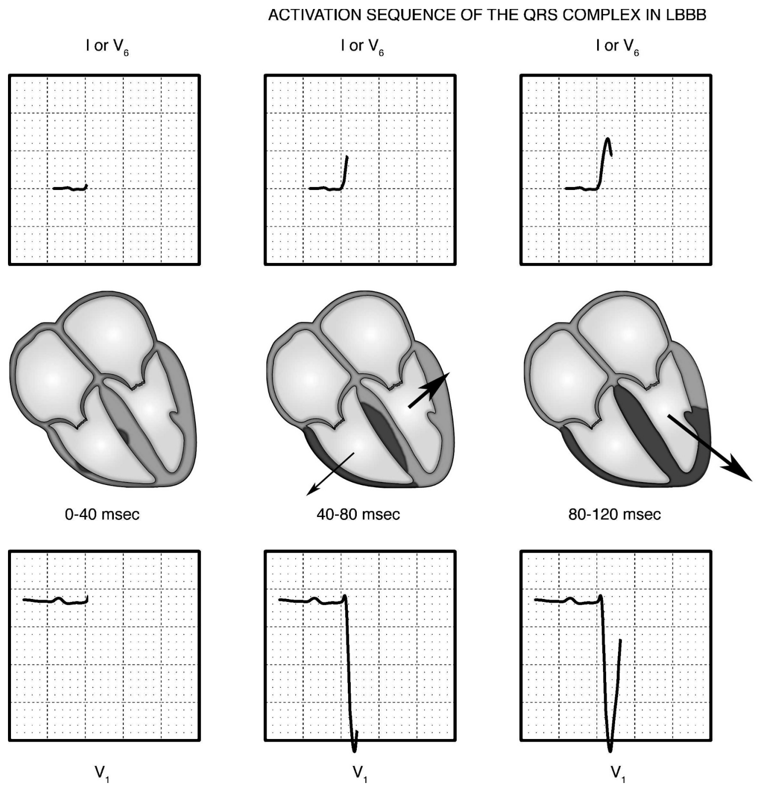
A. The concept of the intrinsicoid deflection time (IDT) delay



B. The genesis of the normal QRS complex in V_1 and I or V_6
   1. Depolarization begins in the left side of the septum and proceeds initially rightward, resulting in a positive deflection in V_1 and a small Q wave in I and V_6.
   2. The bulk of the left ventricle is depolarized next to the left, producing a negative deflection in V_1 and a tall R wave in I and V_6.
   3. Depolarization of the right ventricle (RV) via the right bundle occurs slightly after the onset of left ventricle (LV) depolarization, and any contribution of the RV to the QRS vector is swamped by the electrical forces of the much more massive LV.

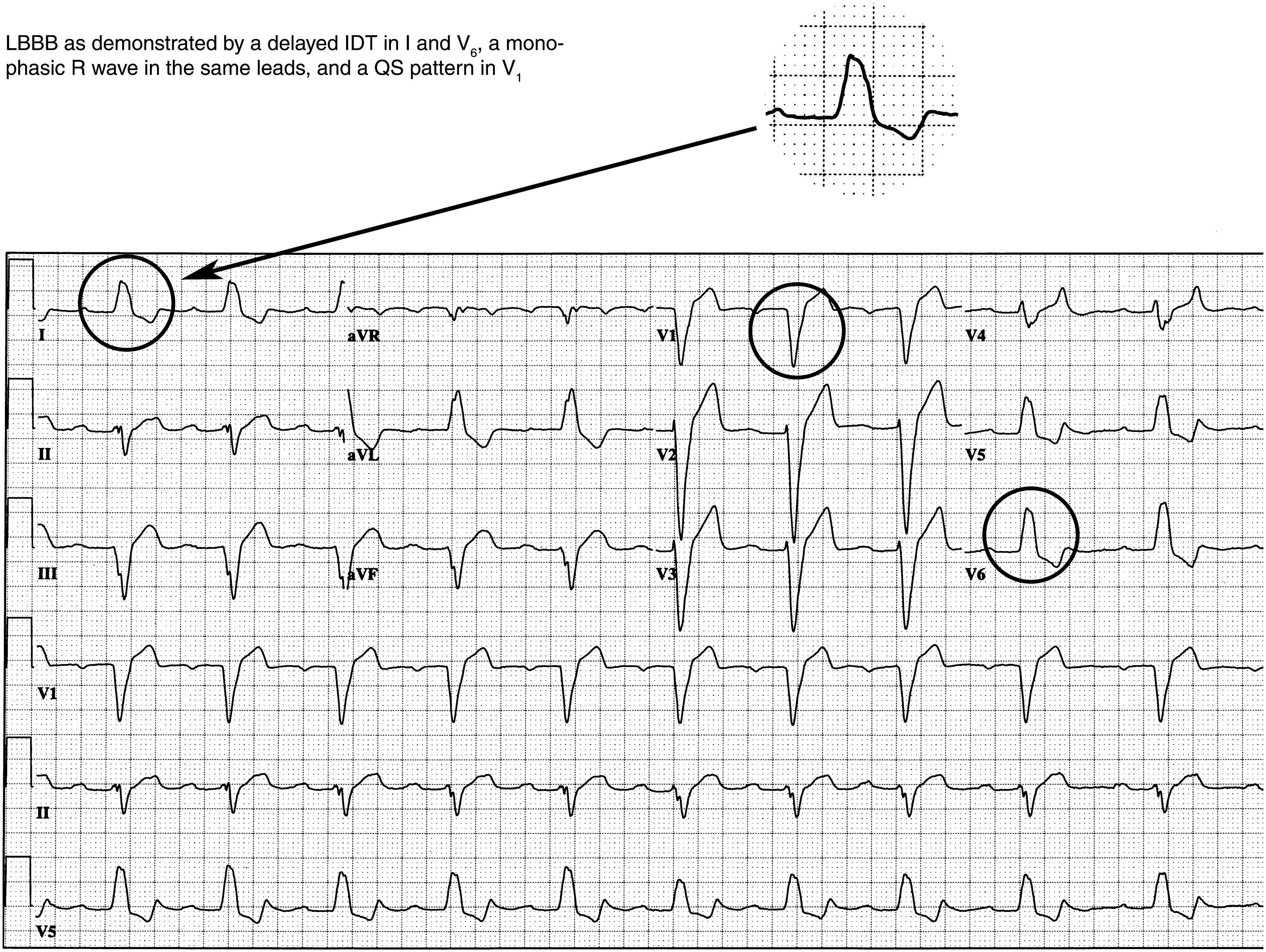


C. The genesis of the QRS complex in LBBB (Day 2-10) (Day 2-11)
   1. In LBBB, the septum is depolarized initially by the right bundle from right to left, producing an initial small Q wave in V_1 and an R wave in I and V_6.
   2. The remainder of the depolarization of the LV also occurs from right to left, producing a large negative deflection in V_1 and a broad, monophasic R wave in 1 and V_6.
   3. Since virtually the entire LV has to be depolarized by movement of current through the myocardium instead of the left bundle, LV activation is delayed in the left chest leads resulting in a delay in the intrinsicoid deflection time in I and V_6.



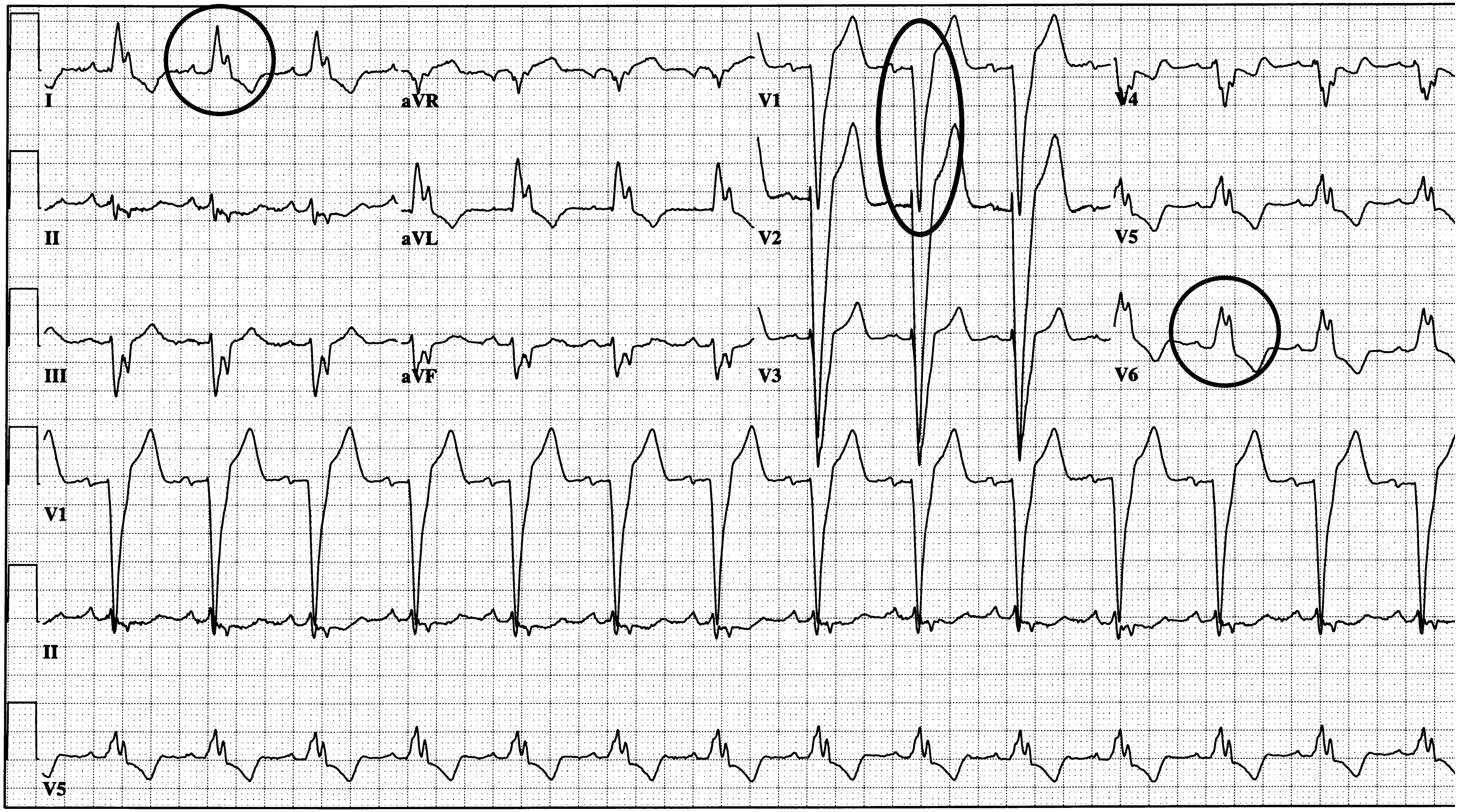
DAY 2-10

LBBB as demonstrated by a delayed IDT in I and V_6, a monophasic R wave in the same leads, and a QS pattern in V_1

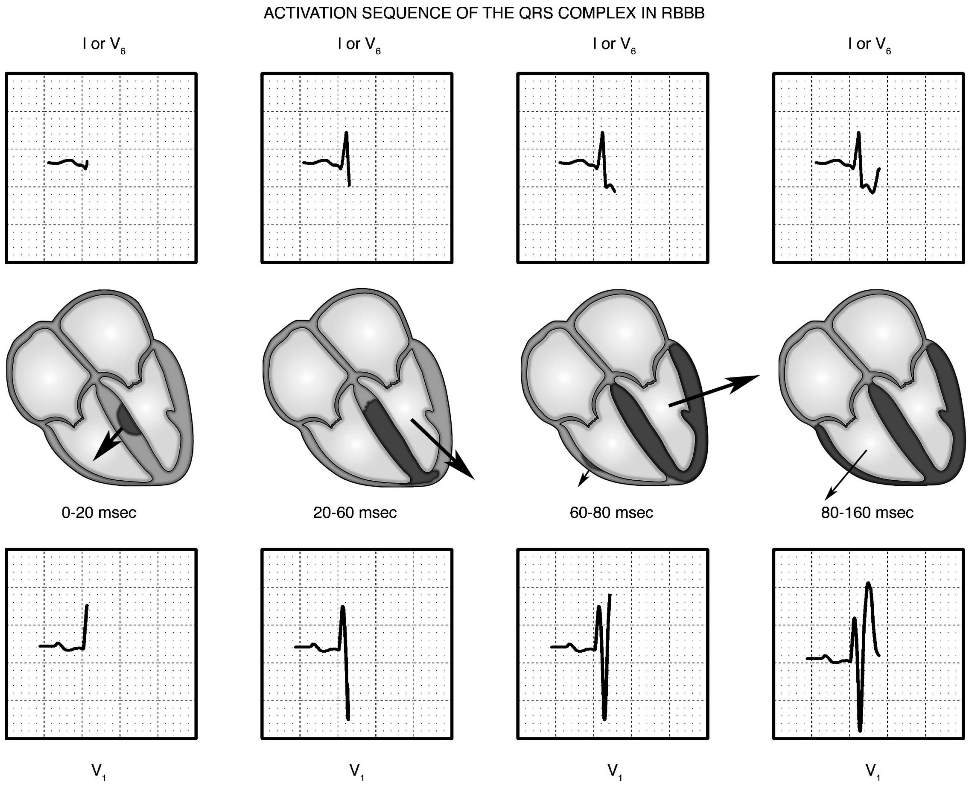


DAY 2-11

LBBB as demonstrated by a delayed IDT in I and V_6, a monophasic R wave in the same leads, and a QS pattern in V_1



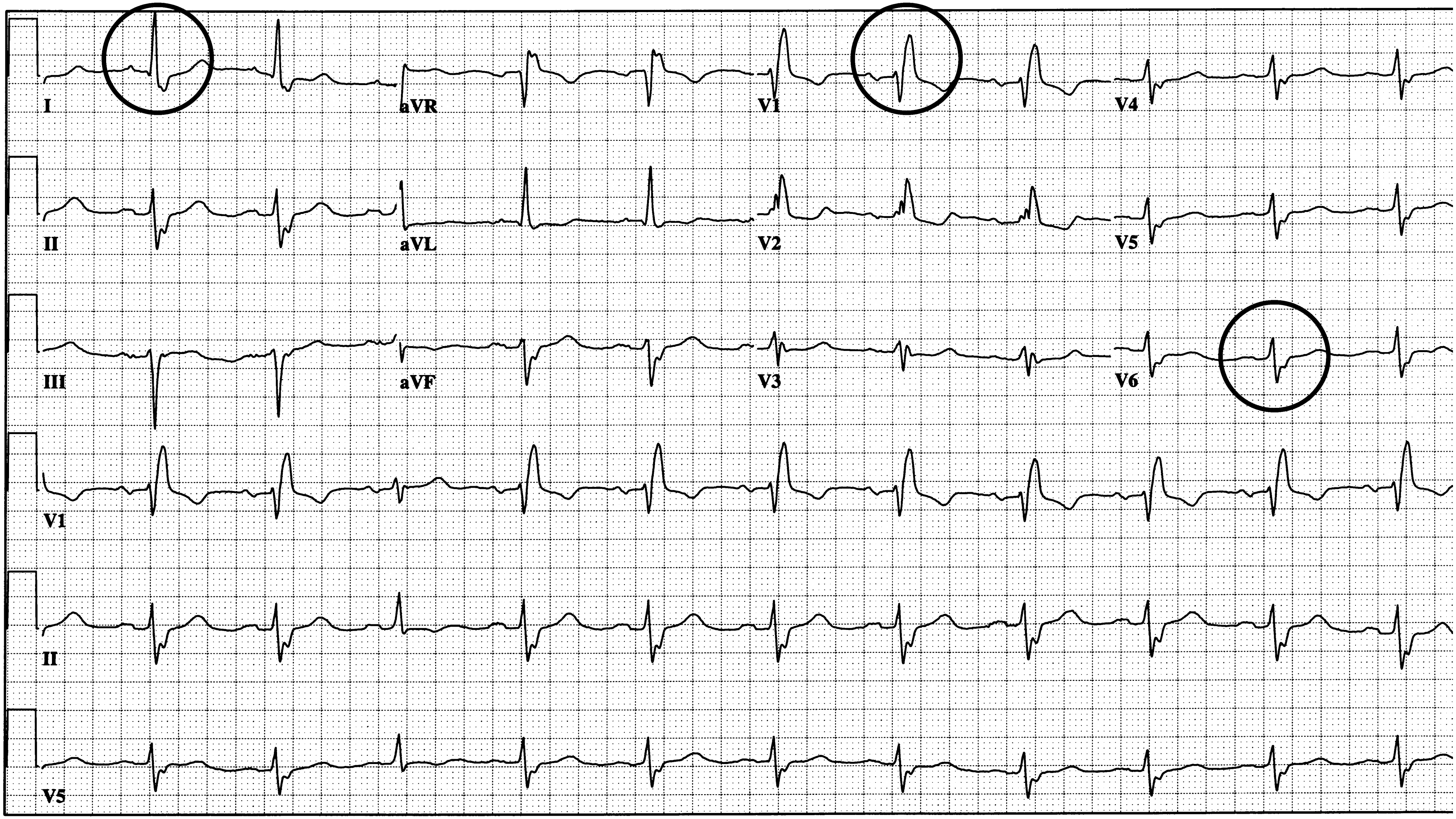
D. The genesis of the QRS complex in RBBB (Day 2-12) (Day 2-13) (Day 2-14)
   1. In RBBB, depolarization of the septum (contributed by the left bundle) occurs normally from left to right, producing a small R wave in V_1.
   2. Depolarization of the LV proceeds normally, producing a negative deflection in V_1 and an R wave in I and V_6.
   3. Finally the RV depolarizes from left to right by movement of current through the myocardium, producing a tall R' wave in V_1 and a wide S wave in I and V_6.
   4. The very late depolarization of the RV produces a delay in the intrinsicoid deflection time in V_1.



E. Infarcts in IVCDs
   1. Because the left bundle is responsible for the first 20–30 msec of the QRS complex, the diagnostic implications of Q waves in the presence of RBBB are still valid.
   2. A common combination is RBBB and an old septal myocardial infarction (MI), which produces a QR configuration in V_1 as opposed to the expected RSR'. (Day 2-15)
   3. The diagnosis of an old MI cannot be made in the presence of LBBB.

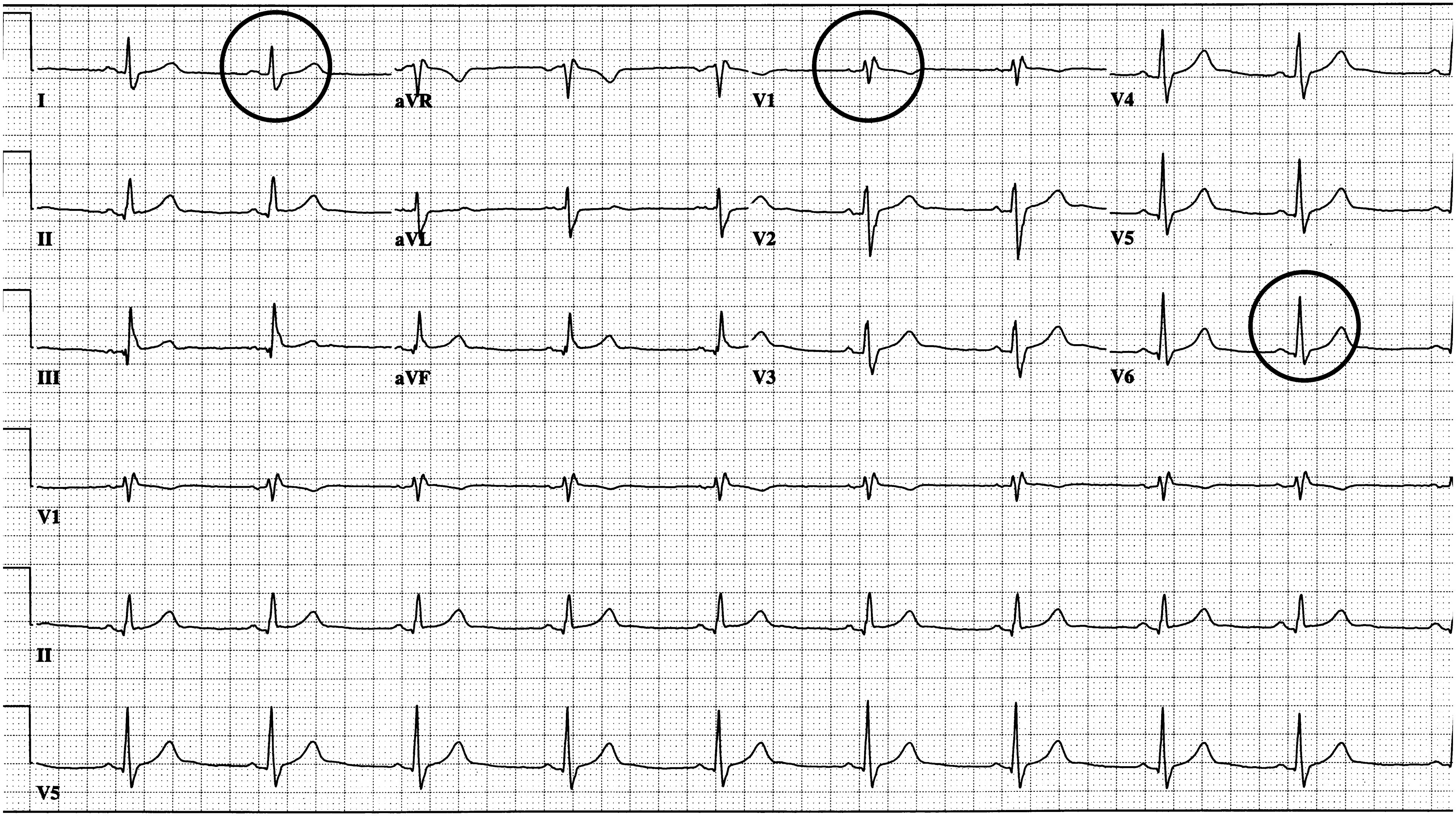
DAY 2-12

RBBB as demonstrated by a QRS duration > 120 msec, a delayed IDT in V_1, an RSR’ in V_1, and a wide S wave in I and V_6



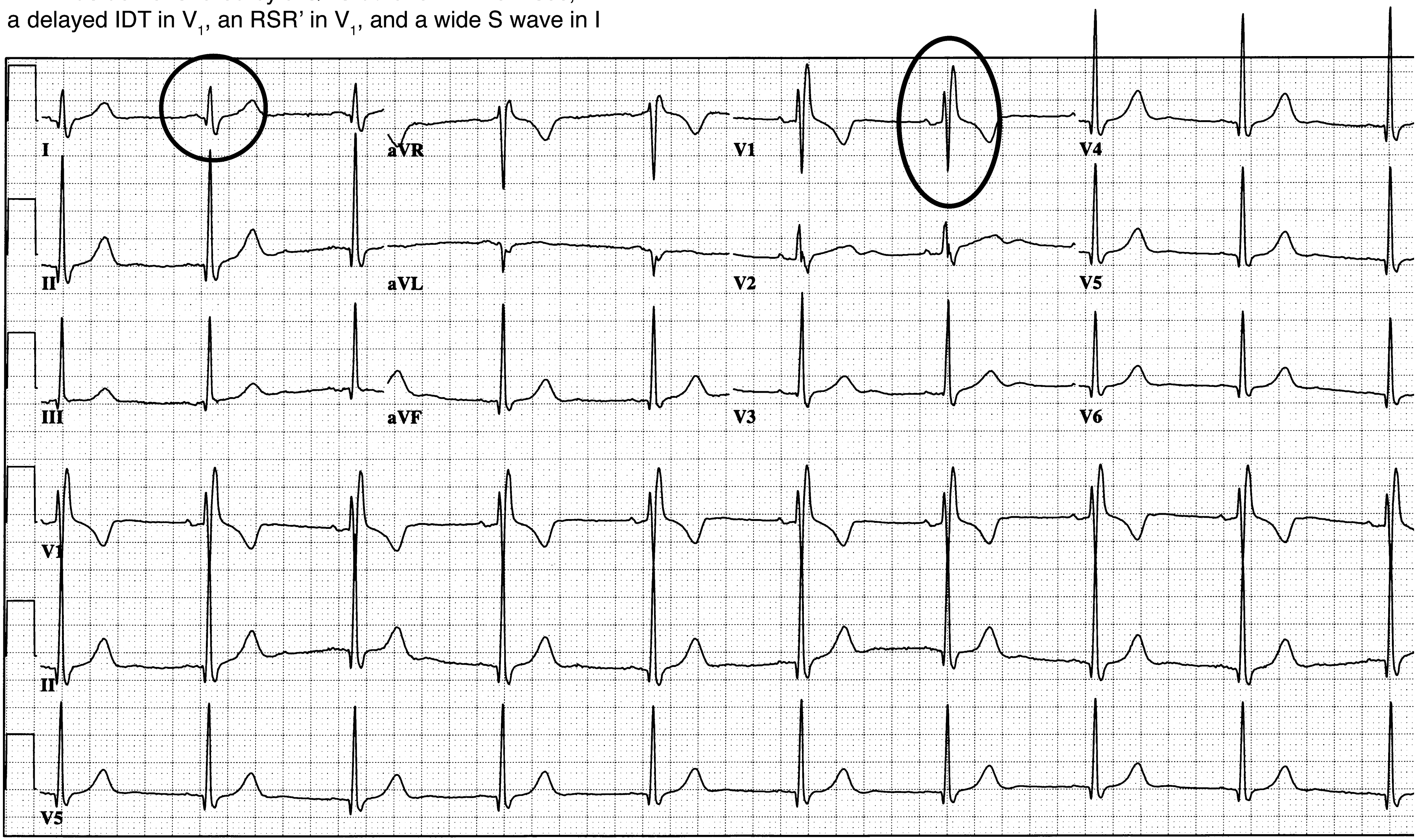
DAY 2-13

Incomplete RBBB as demonstrated by the morphology of complete RBBB, but the QRS duration is not quite 120 msec



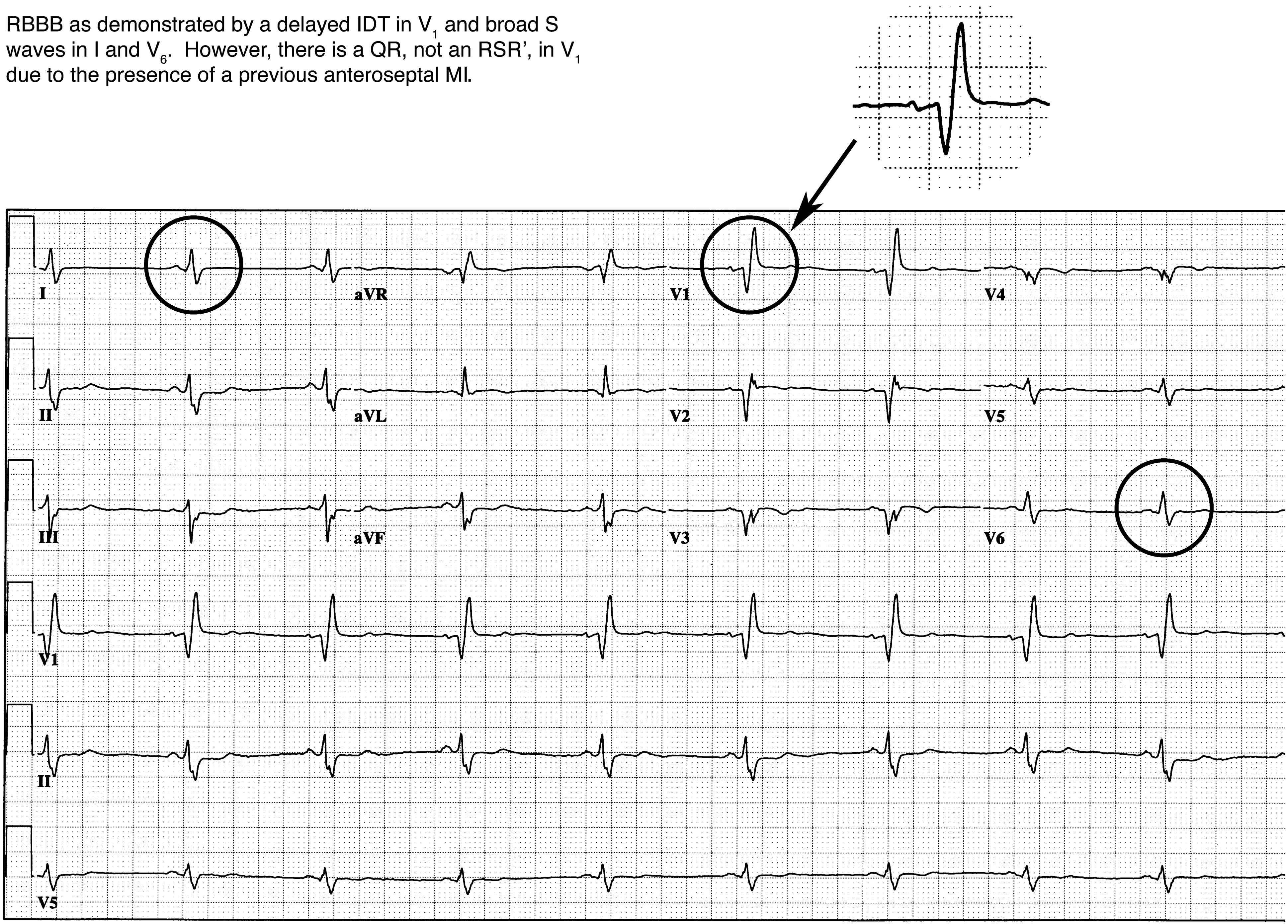
DAY 2-14

RBBB as demonstrated by a QRS duration > 120 msec, a delayed IDT in V_1, an RSR’ in V_1, and a wide S wave in I

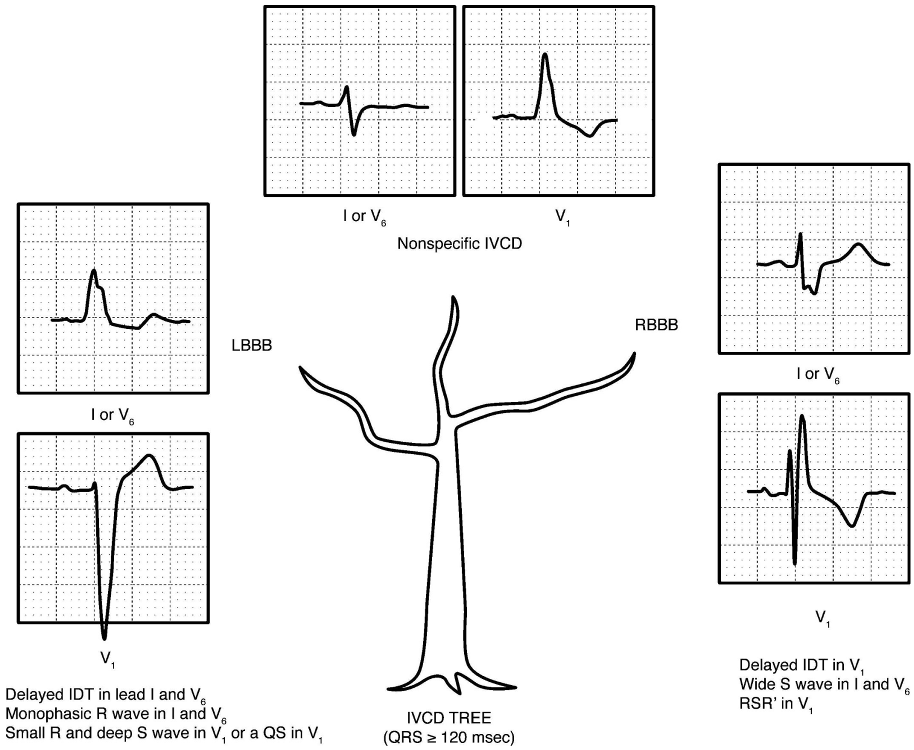


DAY 2-15

RBBB as demonstrated by a delayed IDT in V_1 and broad S waves in I and V_6. However, there is a QR, not an RSR', in V_1 due to the presence of a previous anteroseptal MI.



F. Summary of the rules for naming IVCDs (Day 2-16) (Day 2-17)

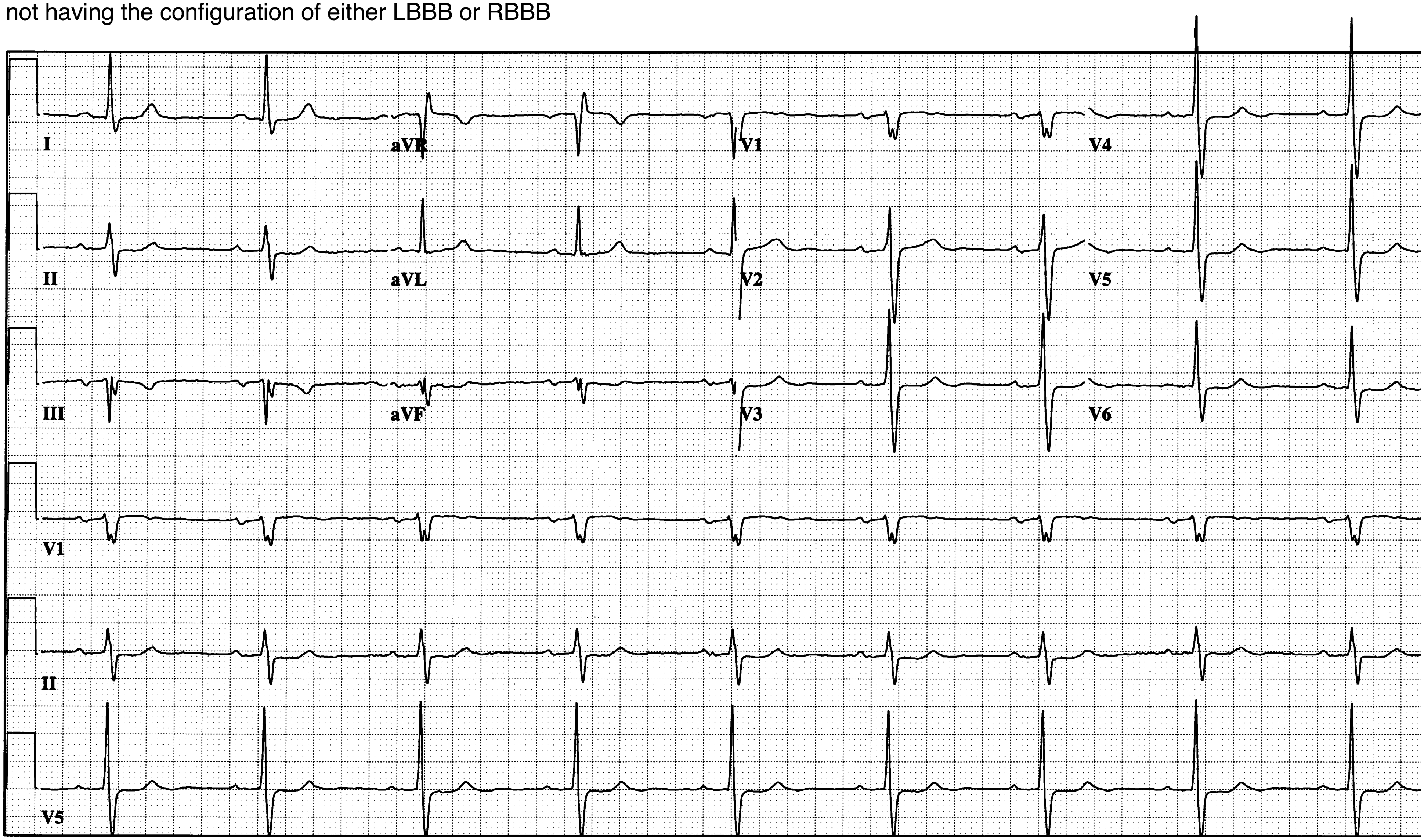


G. Left anterior fascicular block (LAFB) (Day 2-18) (Day 2-19)
   1. Left axis deviation >45°
   2. Tiny Q waves in I or aVL
   3. Usually slightly prolonged QRS duration (>90 msec)
   4. No other causes for LAD (e.g., LVH, inferior MI, chronic lung disease)

H. Left posterior fascicular block (LPFB) (Day 2-20) (Day 2-21)
   1. Right axis deviation >100°
   2. Deep S wave in I and a small Q wave in III
   3. Usually slightly prolonged QRS duration (>90 msec)
   4. No other causes for reactive attachment disorder (RAD) (e.g., RVH, chronic lung disease, lateral MI)

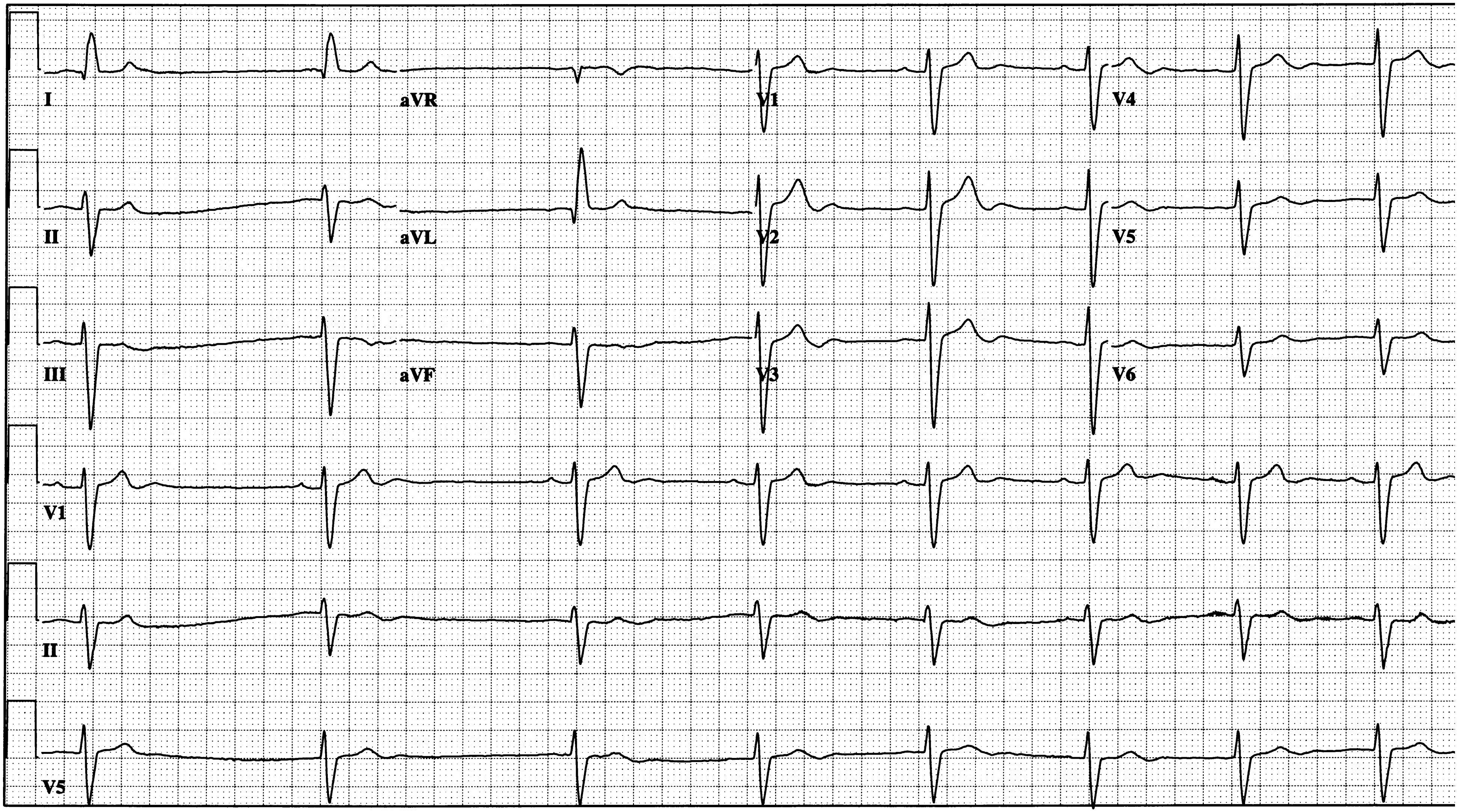
DAY 2-16

Nonspecific intraventricular conduction defect as demonstrated by a QRS duration longer than 120 msec, but not having the configuration of either LBBB or RBBB



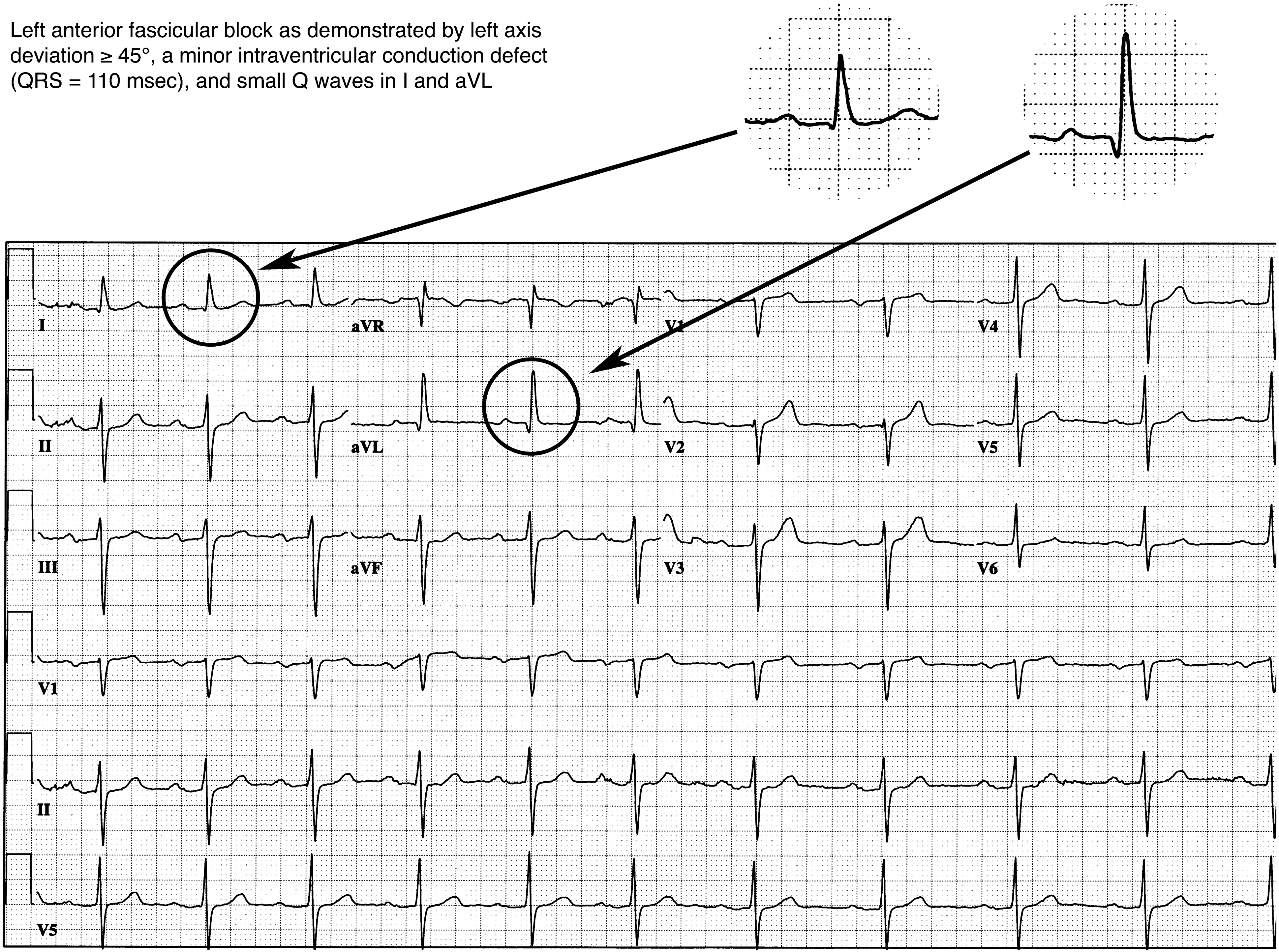
DAY 2-17

Nonspecific intraventricular conduction defect as demonstrated by a QRS duration longer than 120 msec, but not having the configuration of either LBBB or RBBB



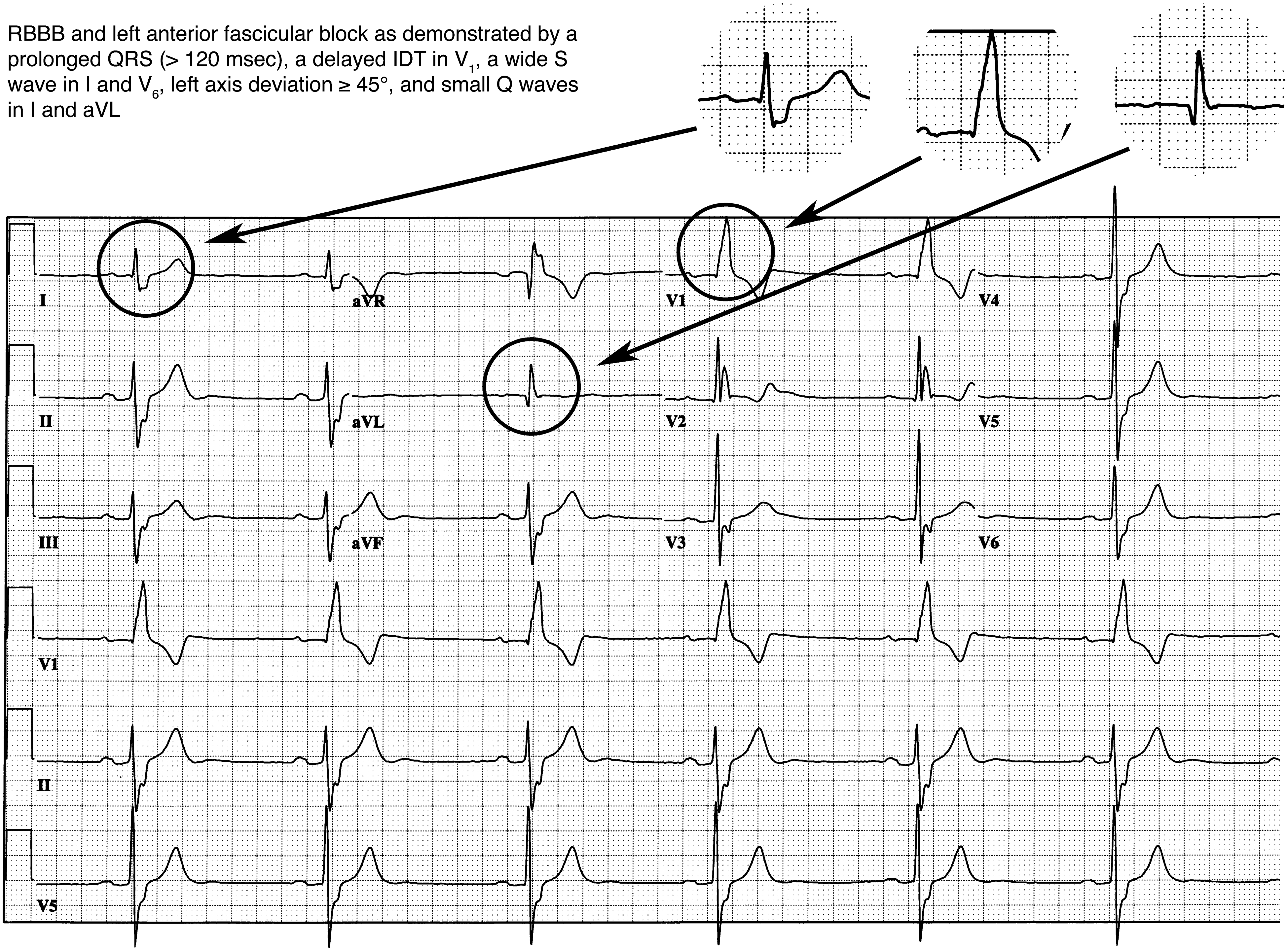
DAY 2-18

Left anterior fascicular block as demonstrated by left axis deviation ≥ 45°, a minor intraventricular conduction defect (QRS = 110 msec), and small Q waves in I and aVL



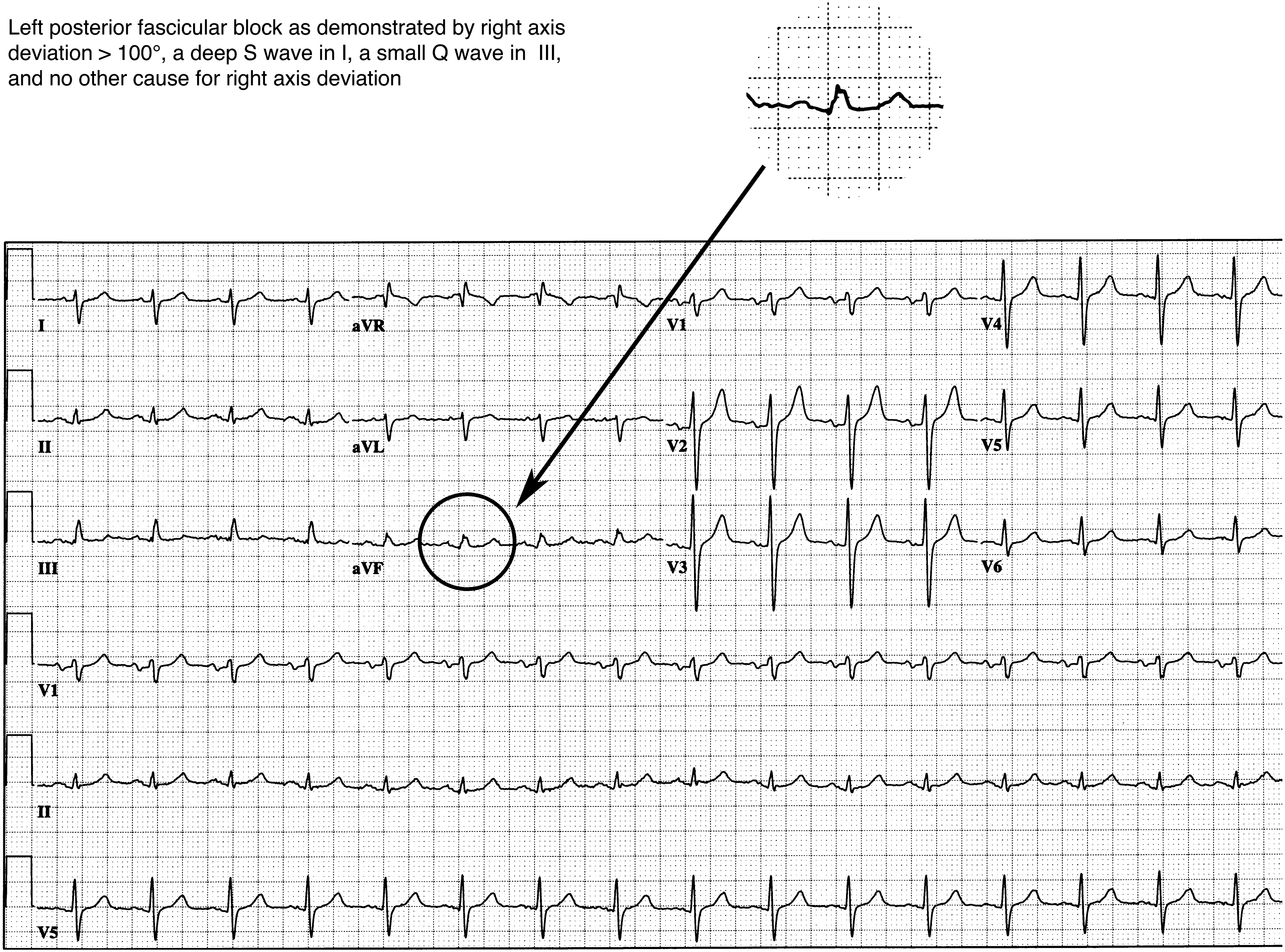
DAY 2-19

RBBB and left anterior fascicular block as demonstrated by a prolonged QRS (> 120 msec), a delayed IDT in V_1, a wide S wave in I and V_6, left axis deviation ≥ 45°, and small Q waves in I and aVL



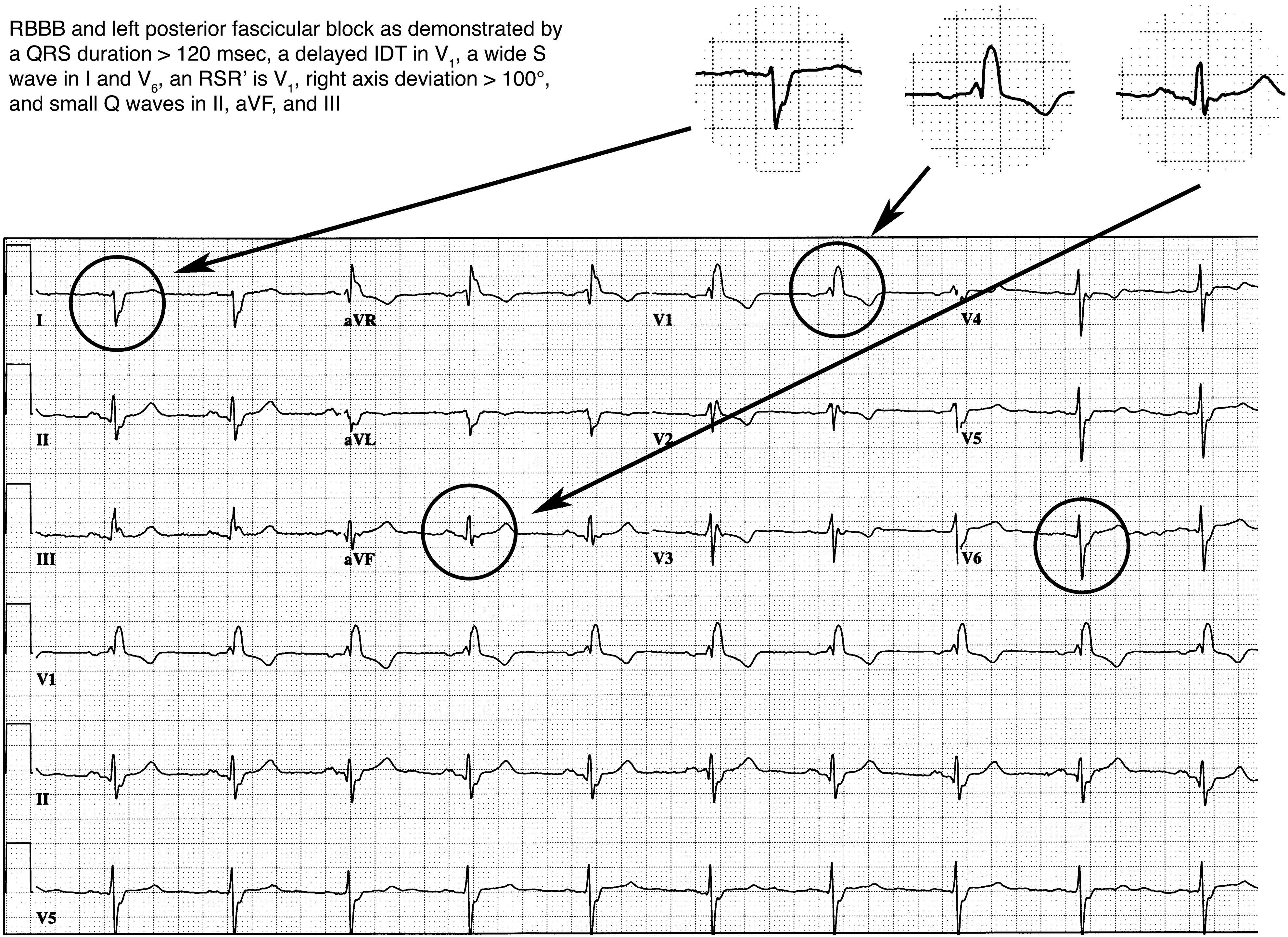
DAY 2-20

Left posterior fascicular block as demonstrated by right axis deviation > 100°, a deep S wave in I, a small Q wave in III, and no other cause for right axis deviation



DAY 2-21

RBBB and left posterior fascicular block as demonstrated by a QRS duration > 120 msec, a delayed IDT in V_1, a wide S wave in I and V_6, an RSR' is V_1, right axis deviation > 100°, and small Q waves in II, aVF, and III



Sample Tracings
ECG 1

Atrial rate: ______________

Ventricular rate: ______________

Rhythm: ______________

P wave: ______________

PR interval: ______________

QRS complex:

Axis: ______________

Duration: ______________

Voltage: ______________

Morphology: ______________

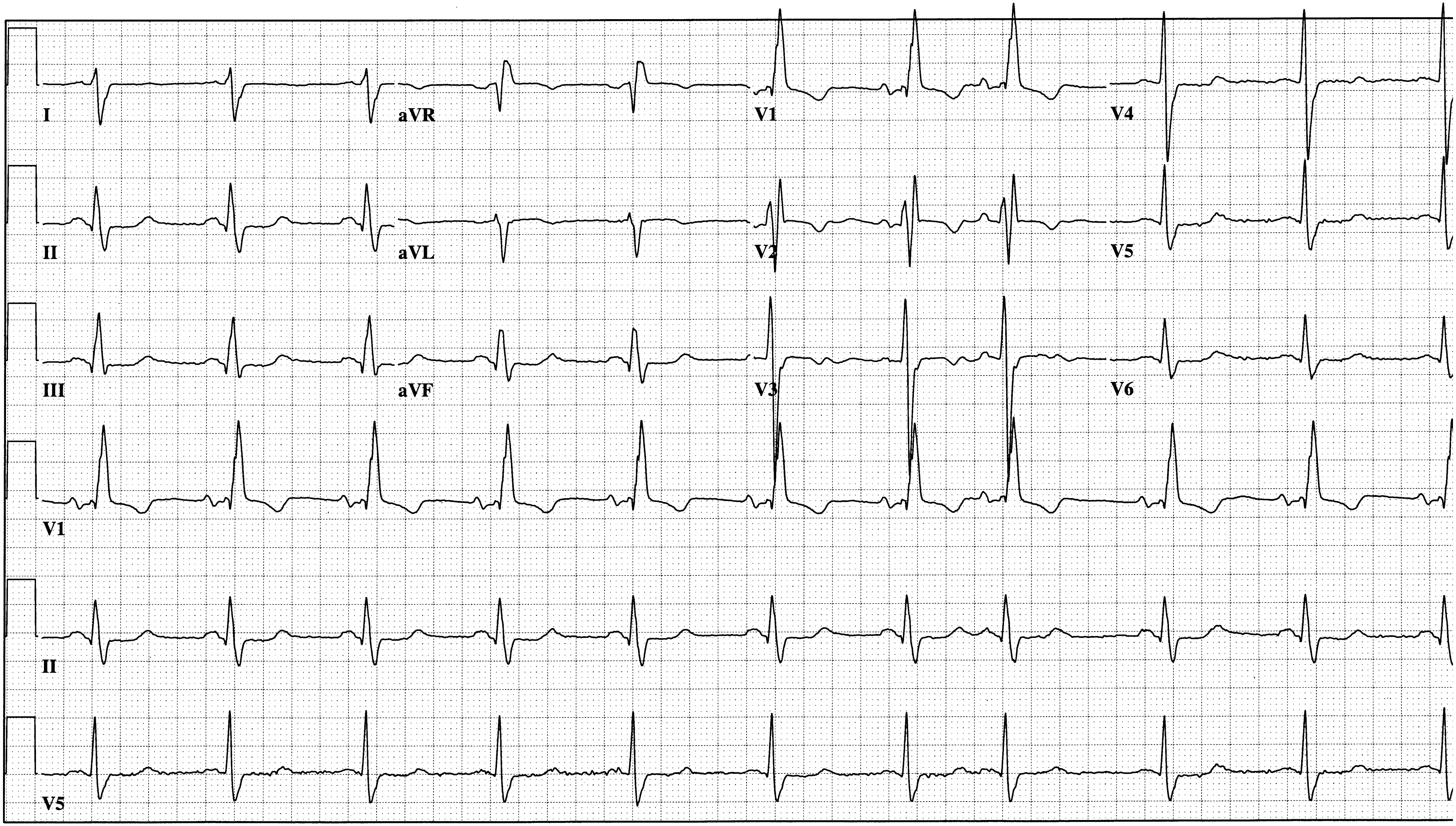
ST segment: ______________

T wave: ______________

QT interval: ______________

U wave: ______________

Diagnosis: ______________



ECG 2

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

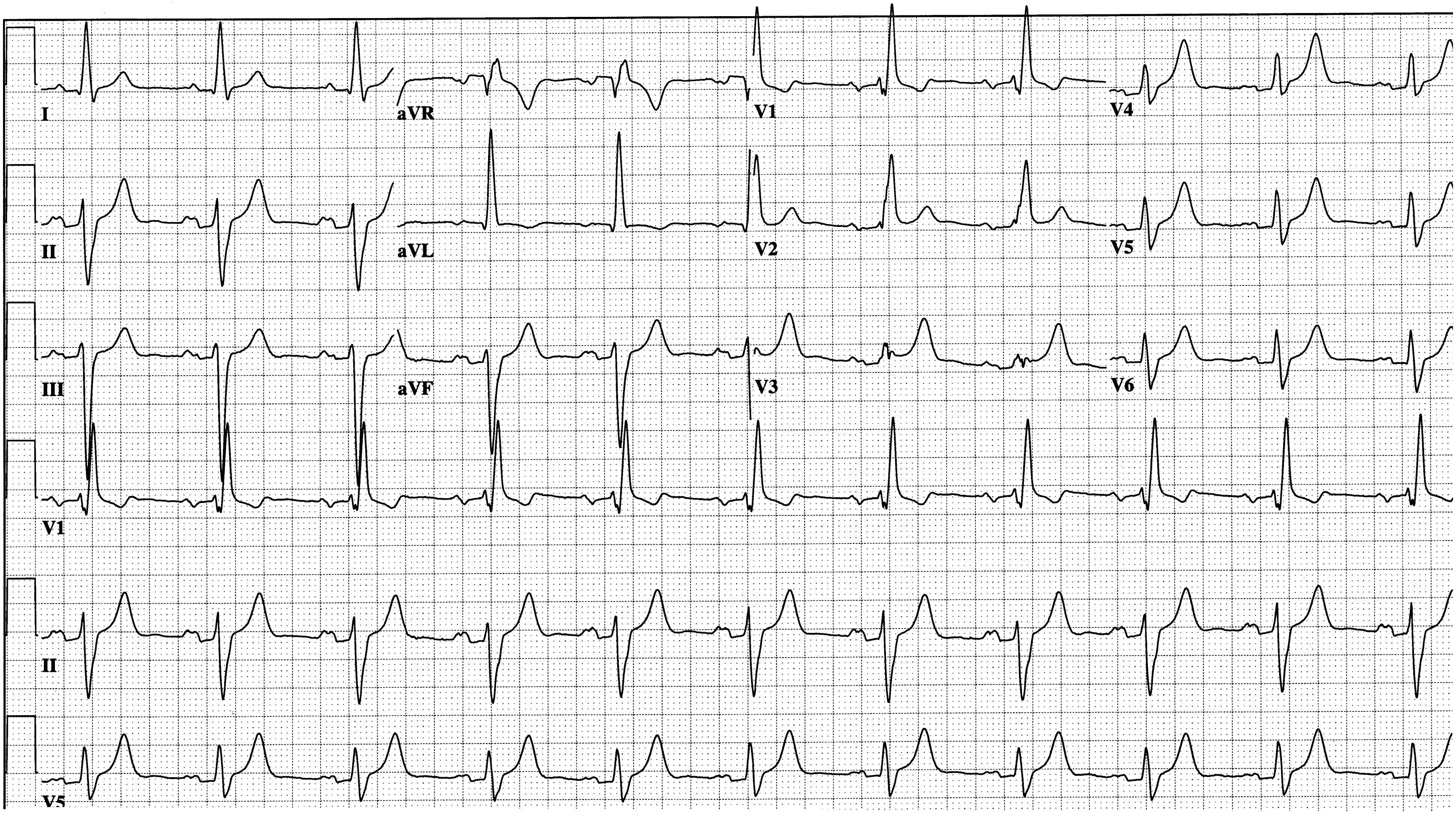
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 3

Atrial rate: ____________

Ventricular rate: ____________

Rhythm: ____________

P wave: ____________

PR interval: ____________

QRS complex:

Axis: ____________

Duration: ____________

Voltage: ____________

Morphology: ____________

ST segment: ____________

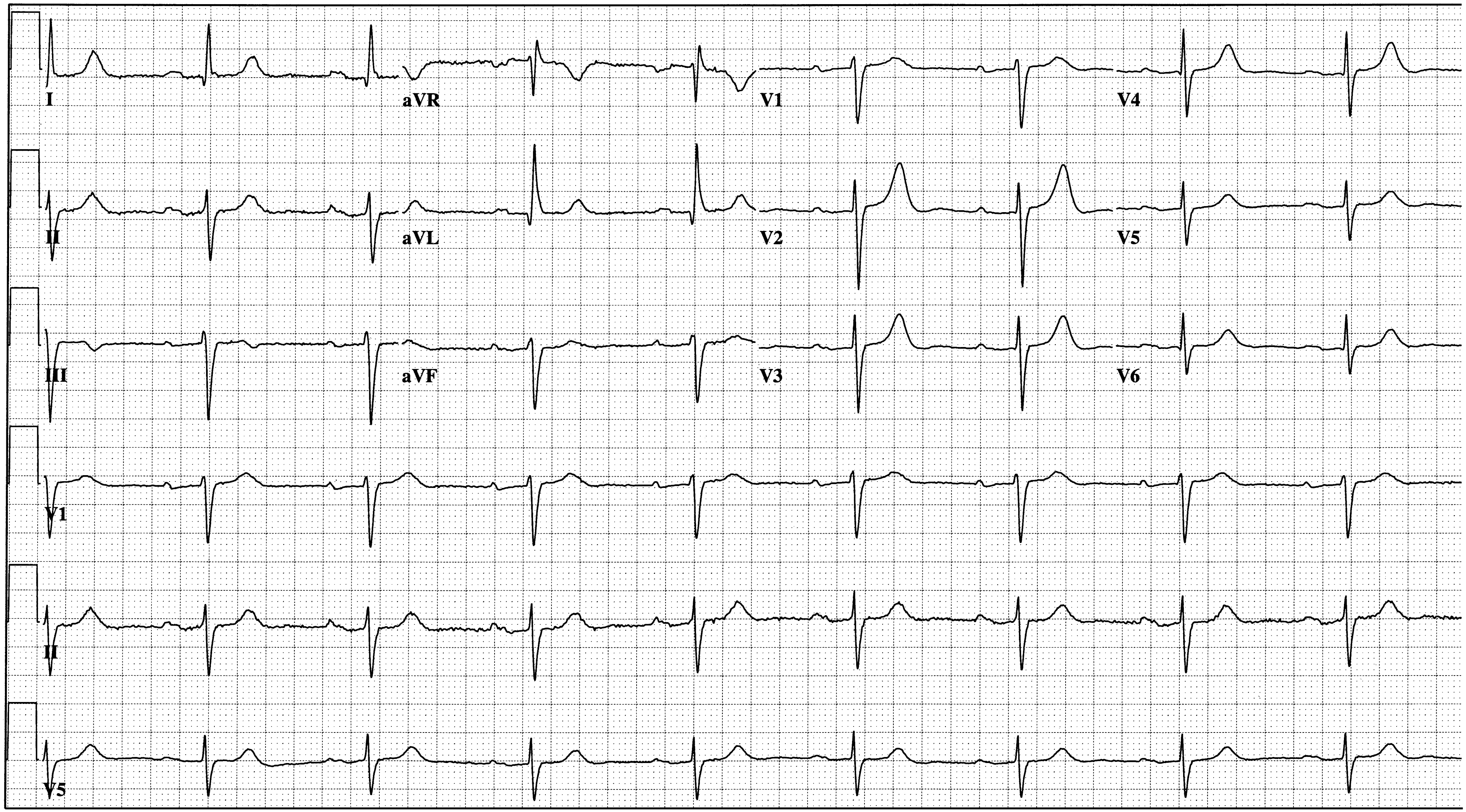
T wave: ____________

QT interval: ____________

U wave: ____________

Diagnosis: ____________

____



ECG 4

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

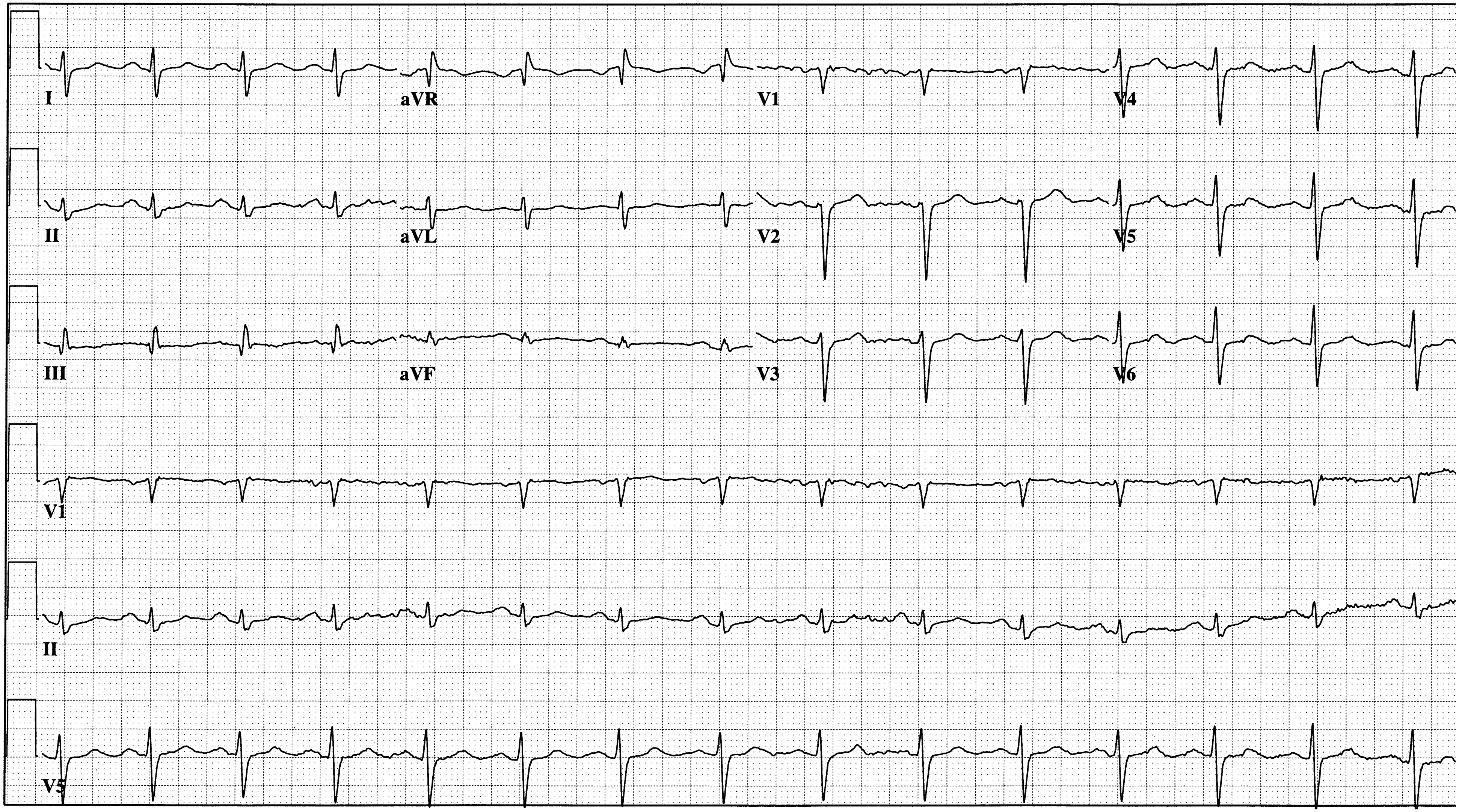
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 5

Atrial rate: ____________

Ventricular rate: ____________

Rhythm: ____________

P wave: ____________

PR interval: ____________

QRS complex:

Axis: ____________

Duration: ____________

Voltage: ____________

Morphology: ____________

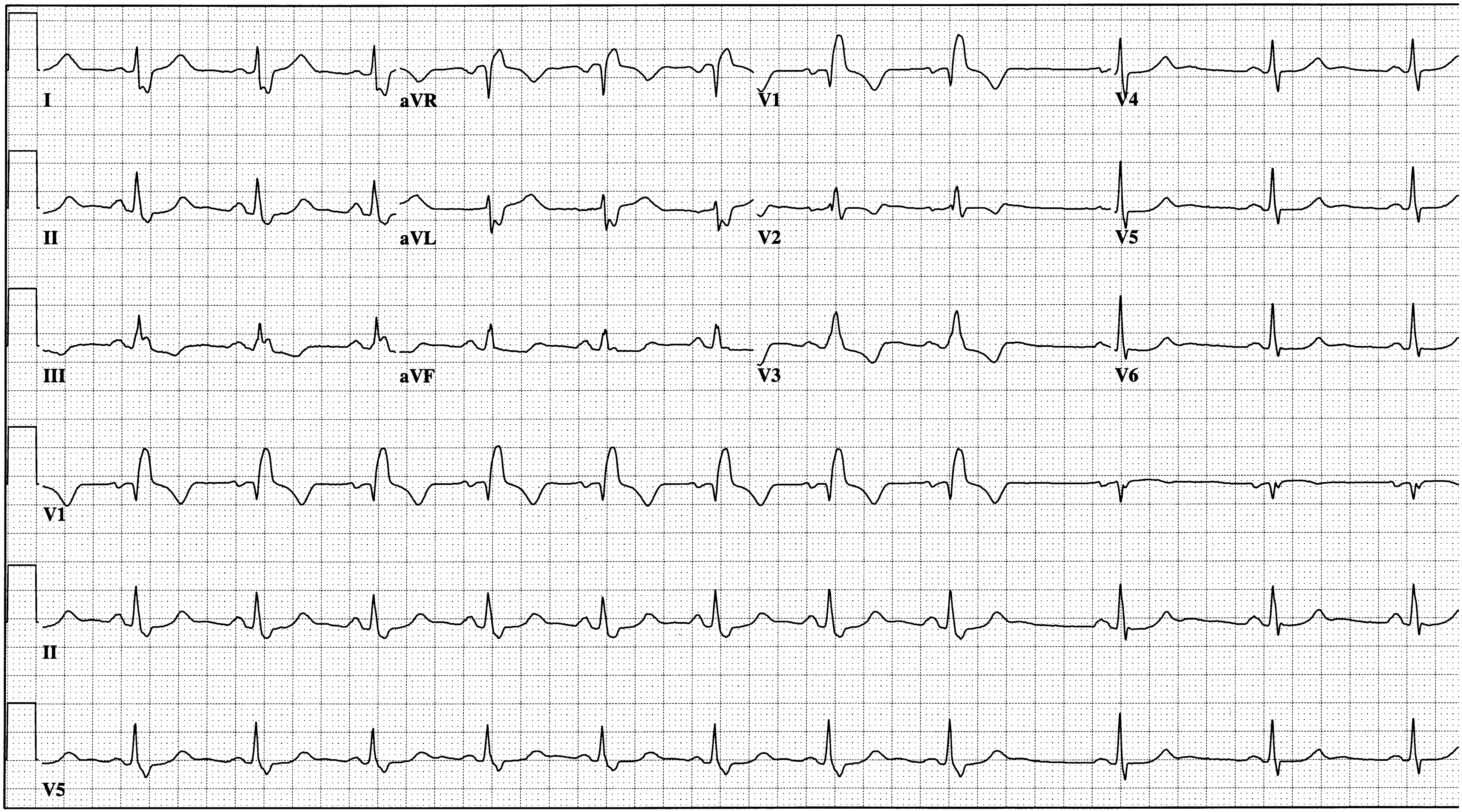
ST segment: ____________

T wave: ____________

QT interval: ____________

U wave: ____________

Diagnosis: ____________



ECG 6

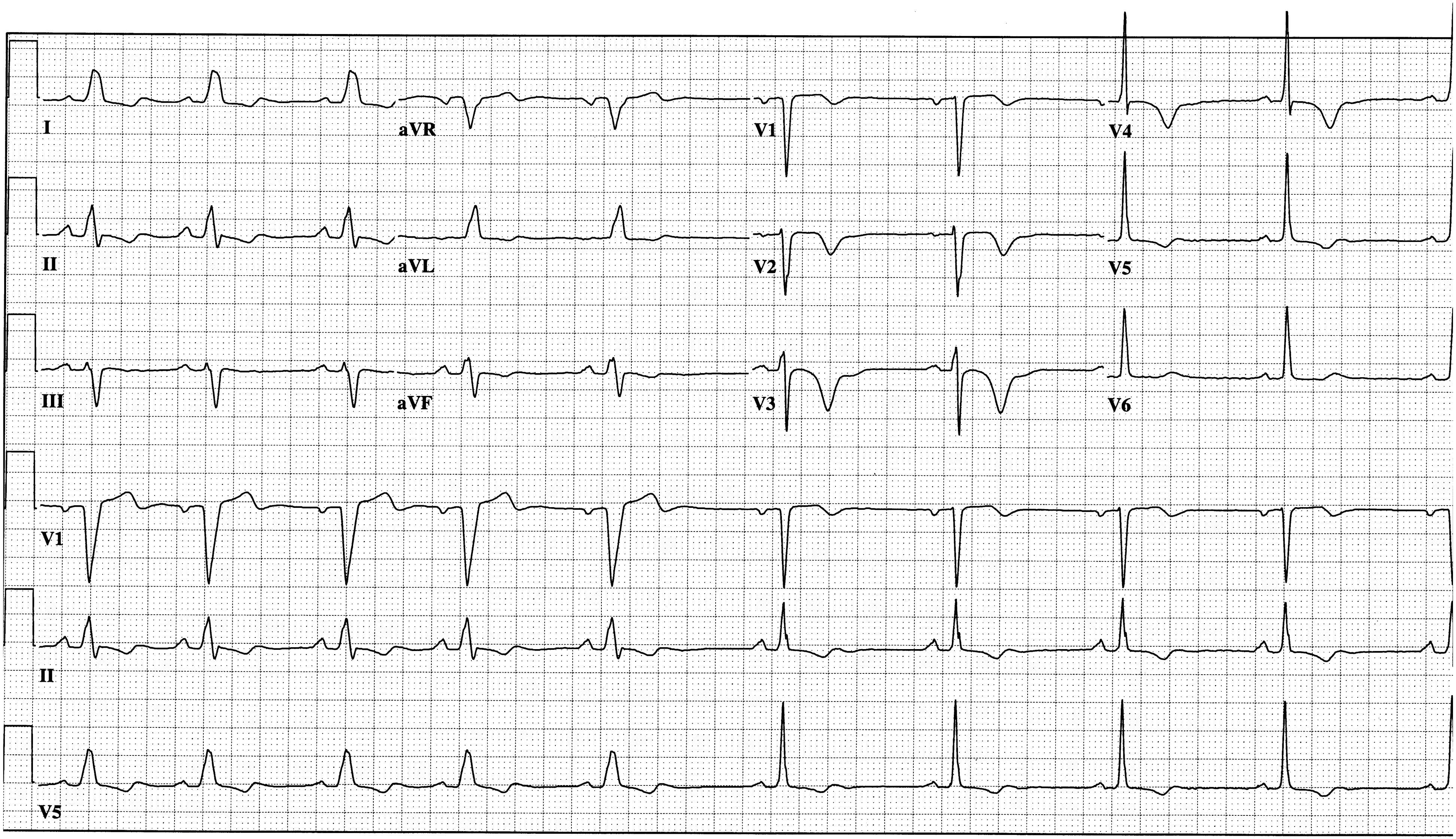
Atrial rate: ______________ QRS complex: ST segment: ______________

Ventricular rate: ______________ Axis: ______________ T wave: ______________

Rhythm: ______________ Duration: ______________ QT interval: ______________

P wave: ______________ Voltage: ______________ U wave: ______________

PR interval: ______________ Morphology: ______________ Diagnosis: ______________

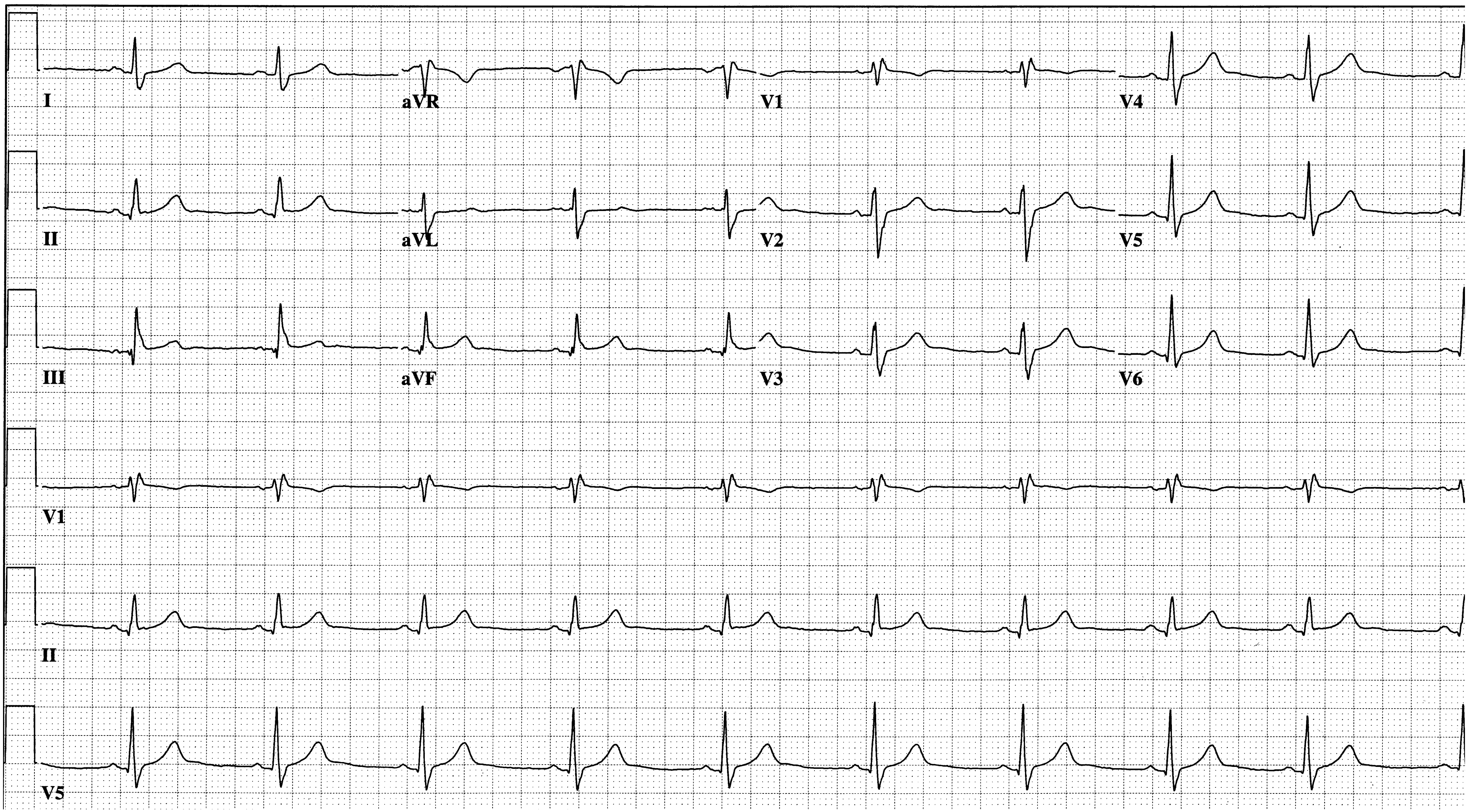


ECG 7

Atrial rate: ______________________
Ventricular rate: ______________________
Rhythm: ______________________
P wave: ______________________
PR interval: ______________________

QRS complex:
Axis: ______________________
Duration: ______________________
Voltage: ______________________
Morphology: ______________________

ST segment: ______________________
T wave: ______________________
QT interval: ______________________
U wave: ______________________
Diagnosis: ______________________
____



ECG 8

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

ST segment: ____________________

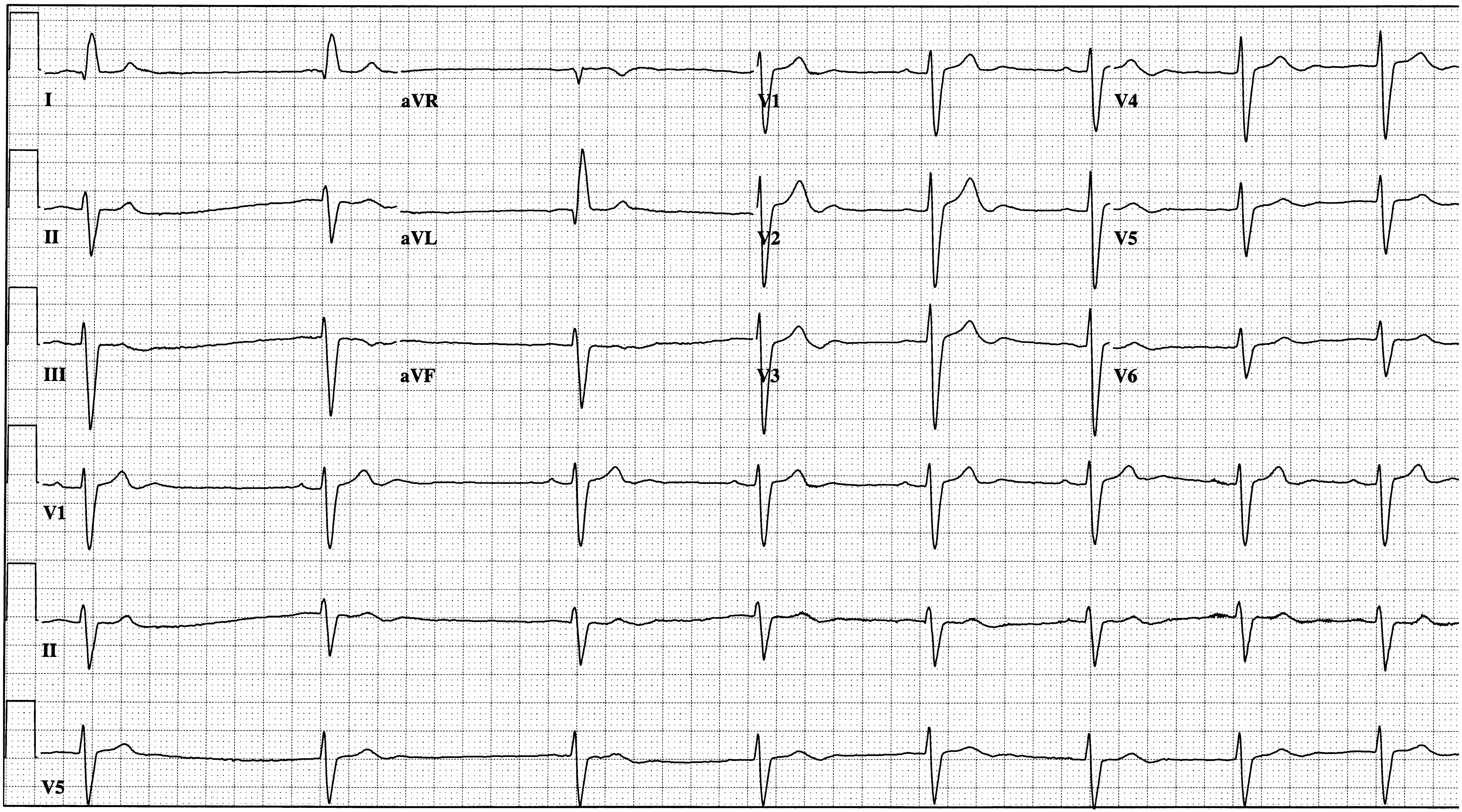
T wave: ____________________

QT interval: ____________________

U wave: ____________________

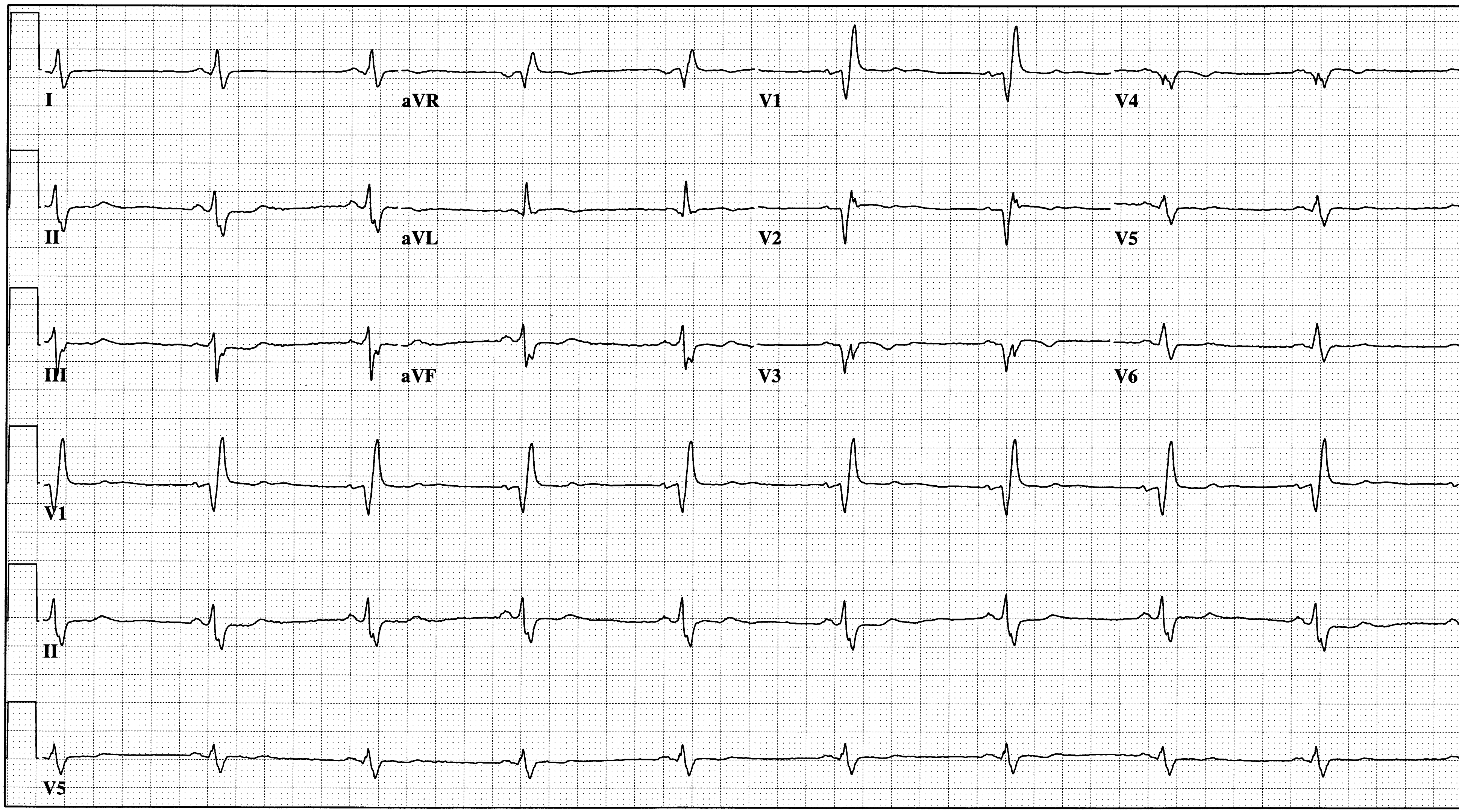
Diagnosis: ____________________

____



ECG 9

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______
		______



ECG10

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

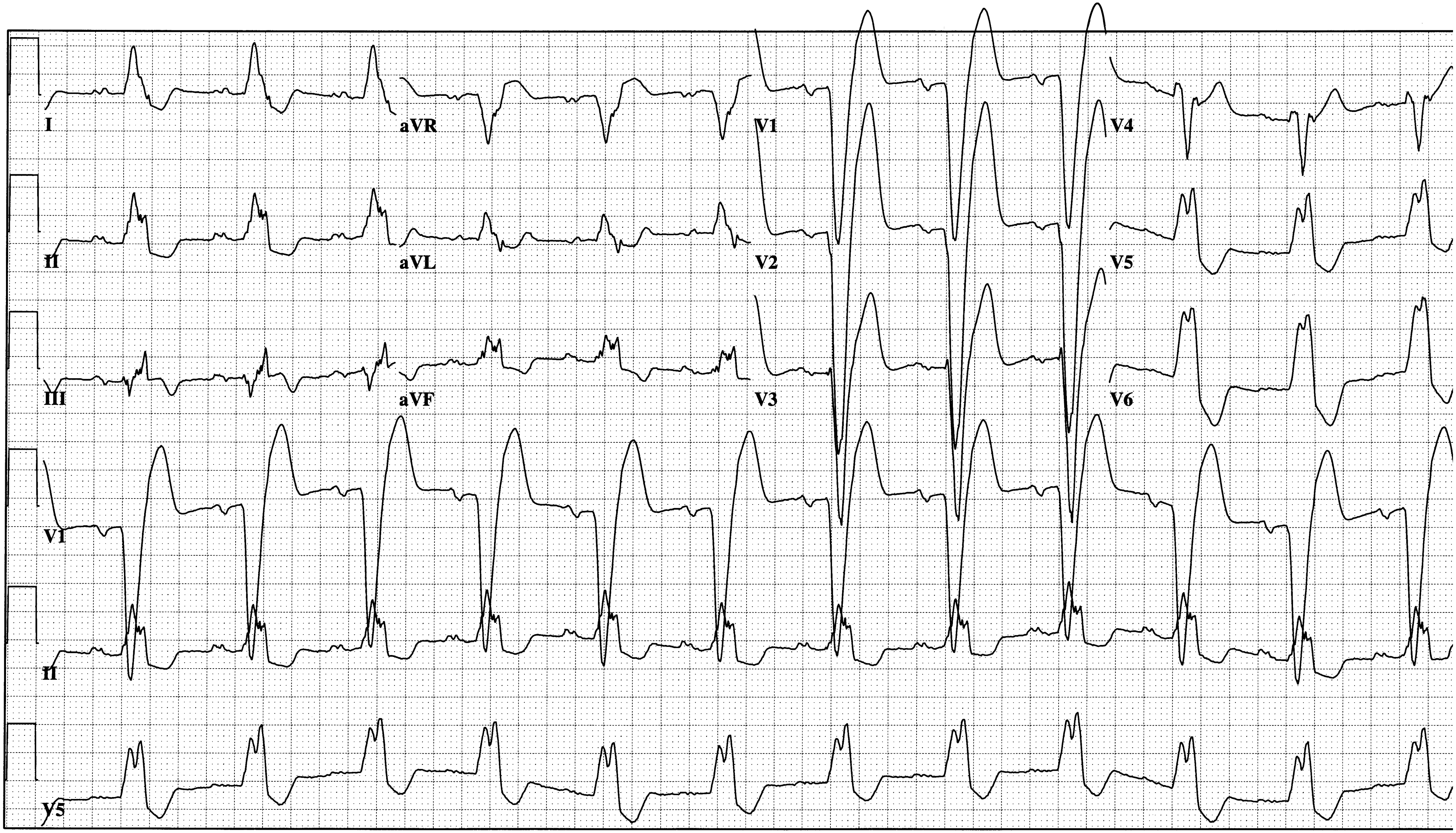
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG 11

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

ST segment: ______

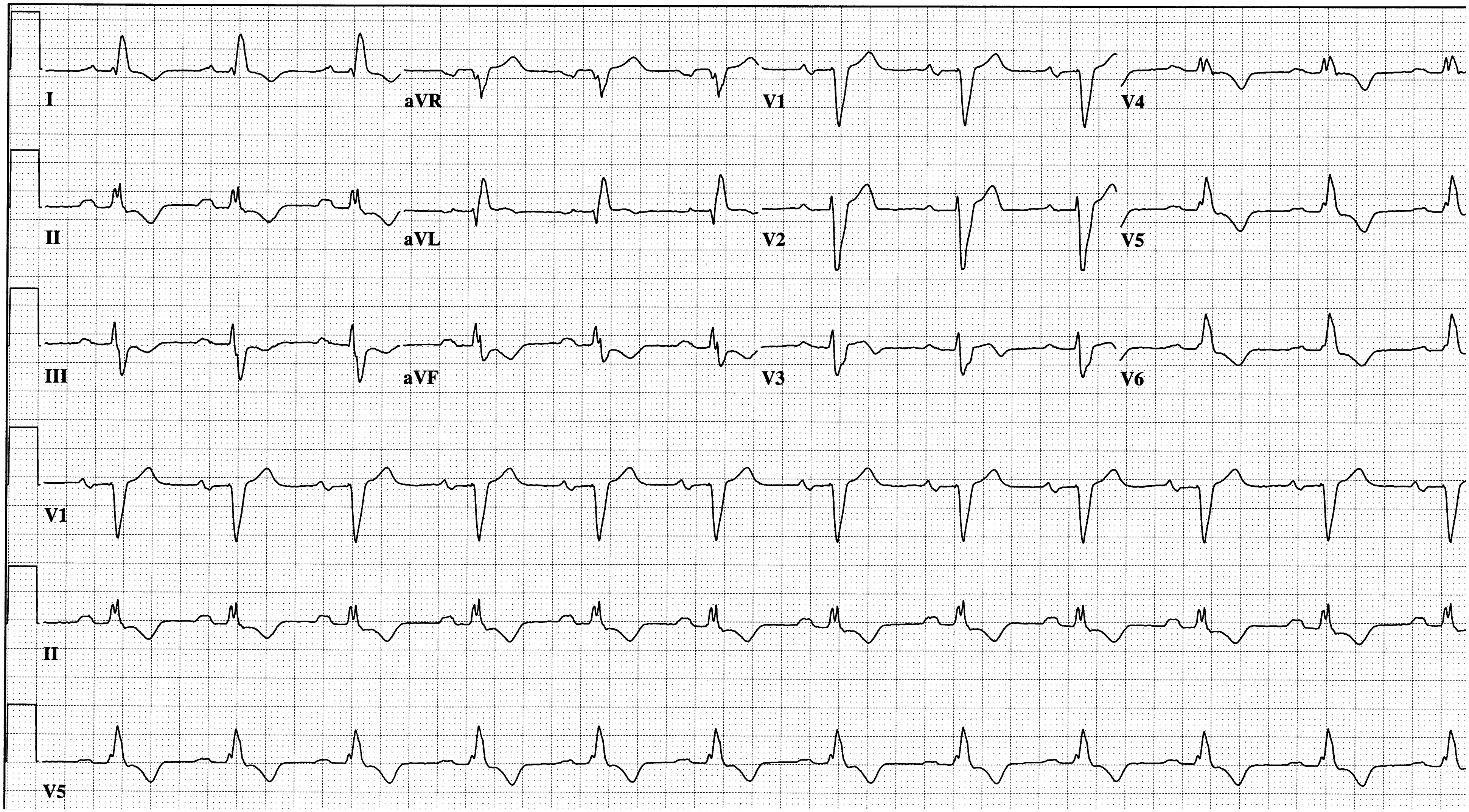
T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______

______



ECG 12

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

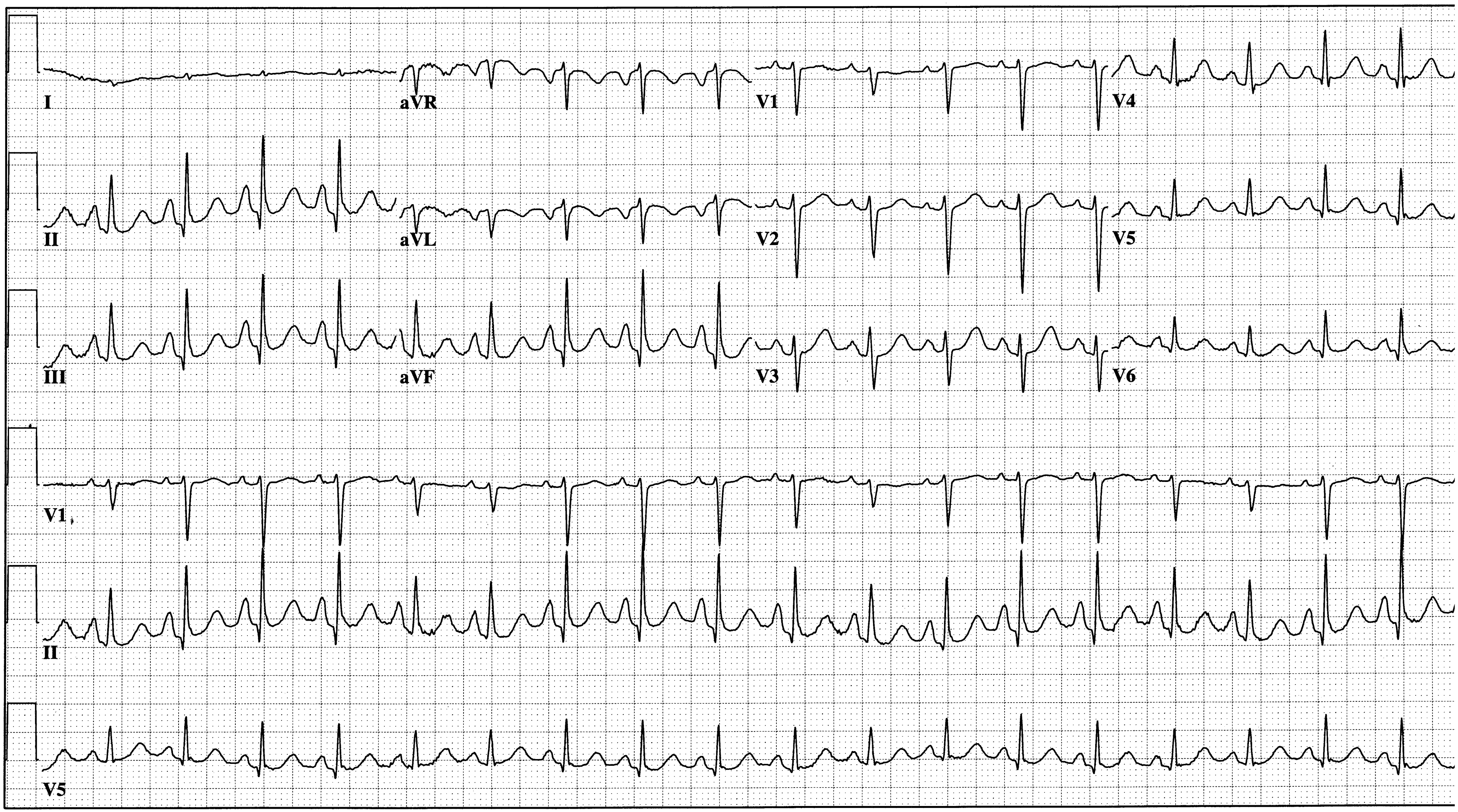
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG 13

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

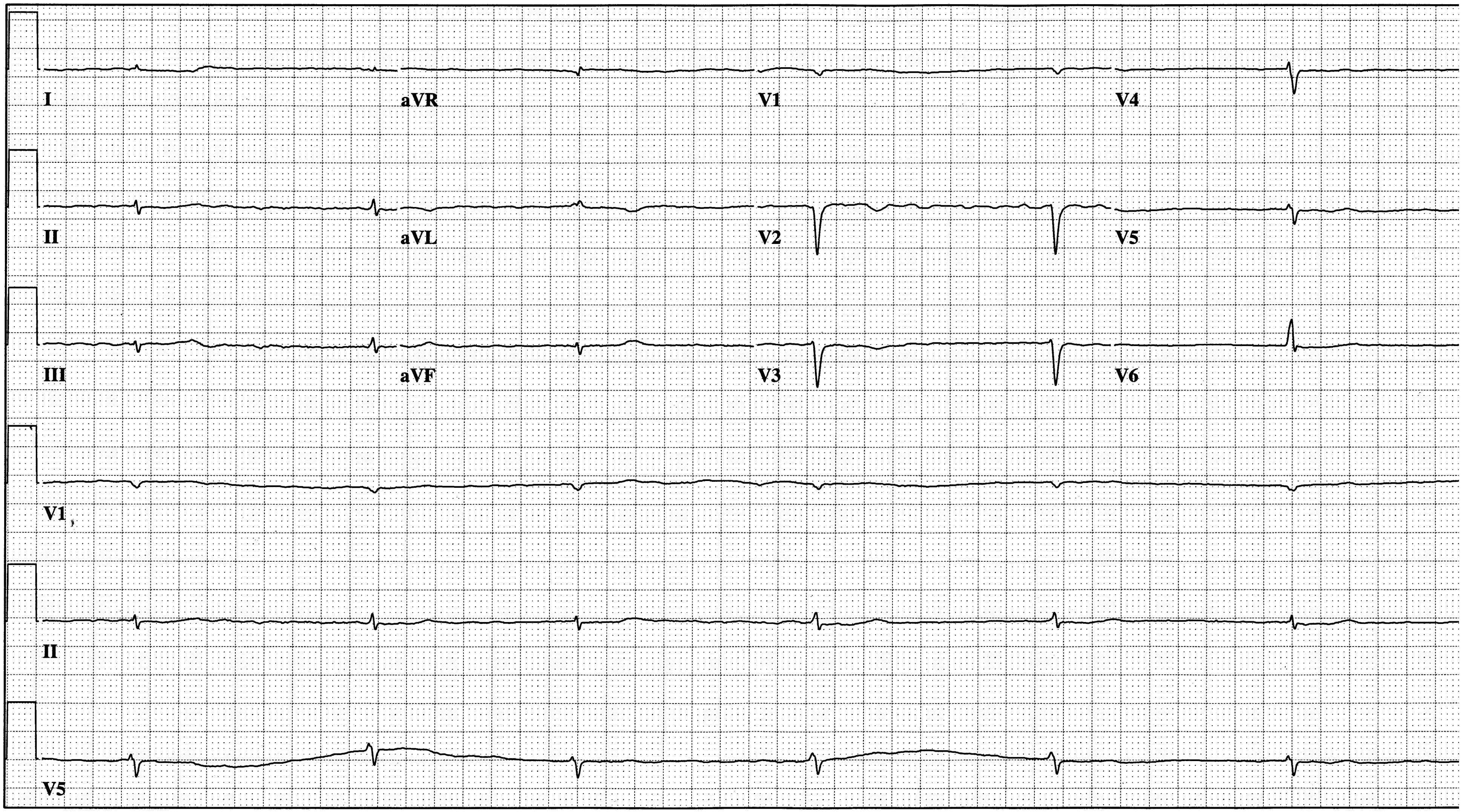
ST segment: ______________________

T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________



ECG 14

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

ST segment: ______

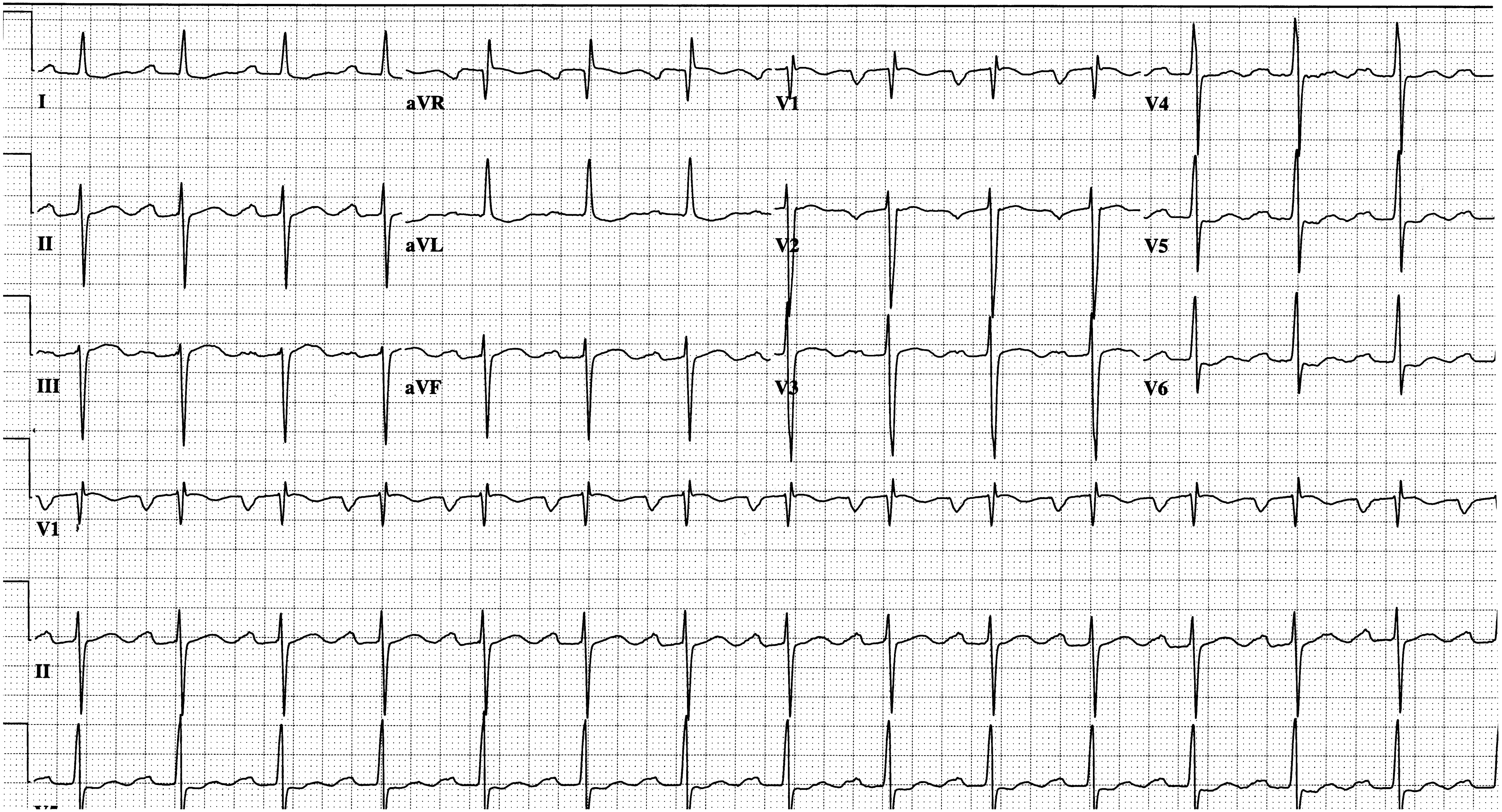
T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______

______



ECG 15

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

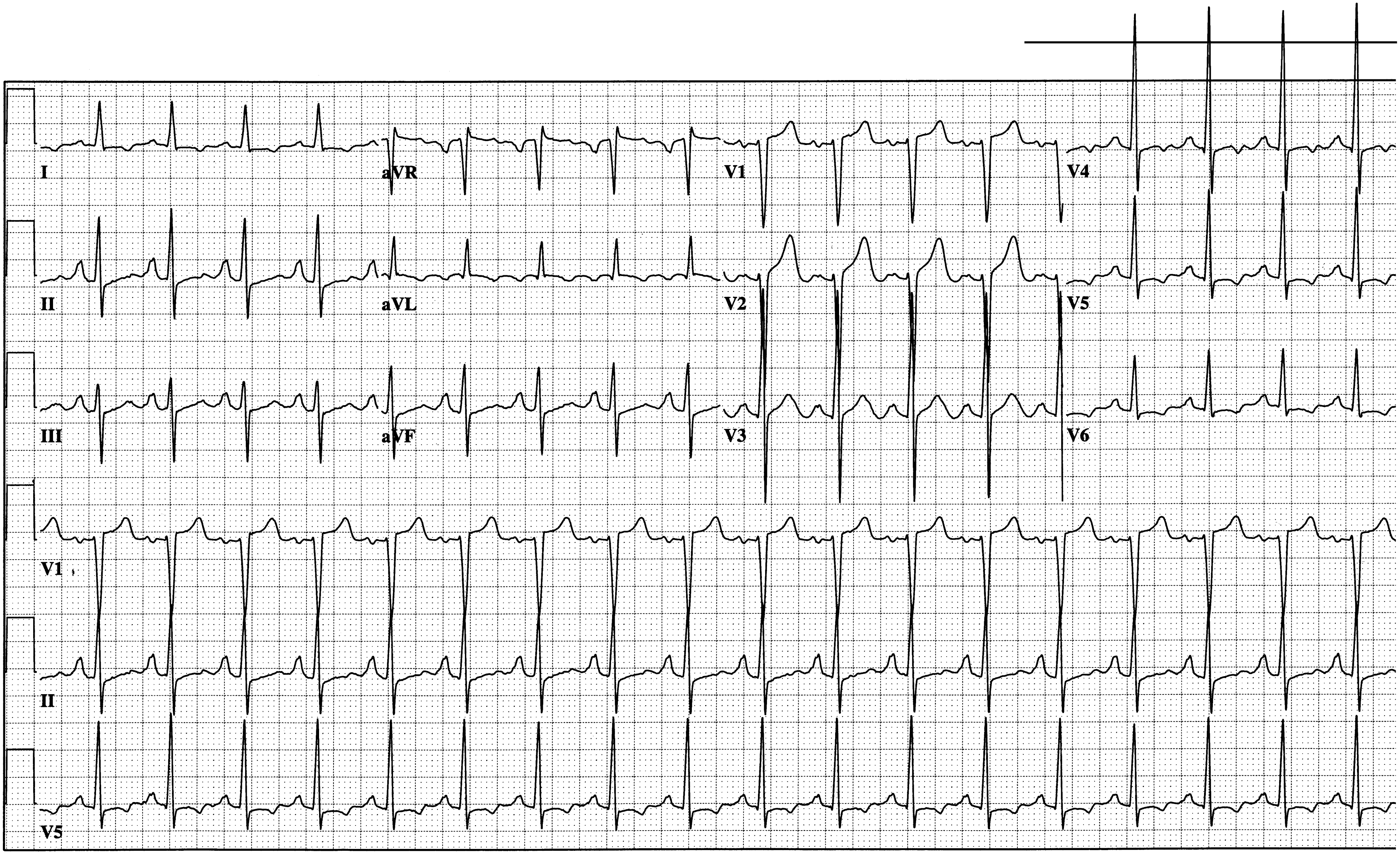
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 16

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

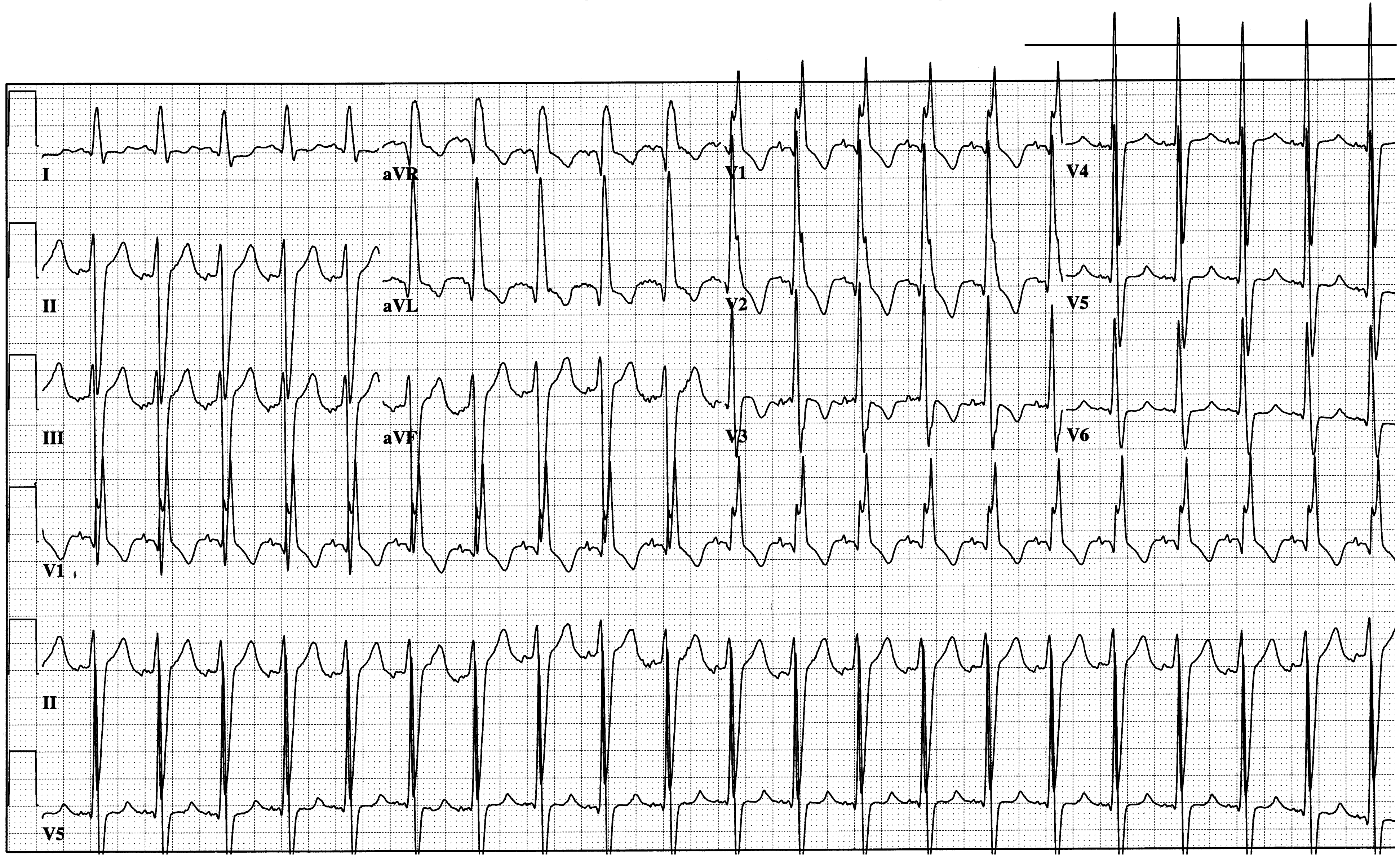
ST segment: ____________________

T wave: ____________________

QT interval: ____________________

U wave: ____________________

Diagnosis: ____________________

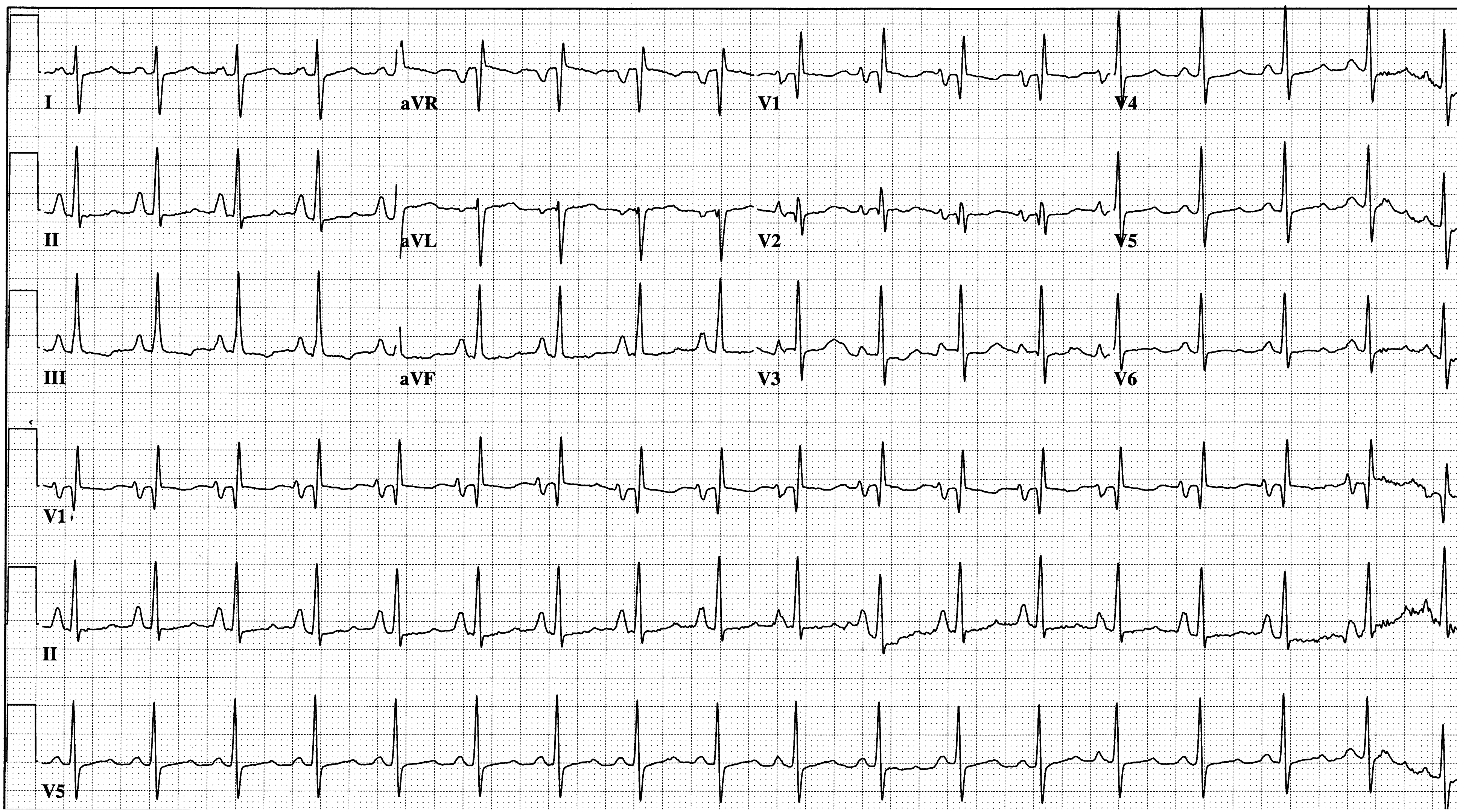


ECG 17

Atrial rate: ______
Ventricular rate: ______
Rhythm: ______
P wave: ______
PR interval: ______

QRS complex:
Axis: ______
Duration: ______
Voltage: ______
Morphology: ______

ST segment: ______
T wave: ______
QT interval: ______
U wave: ______
Diagnosis: ______



ECG 18

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

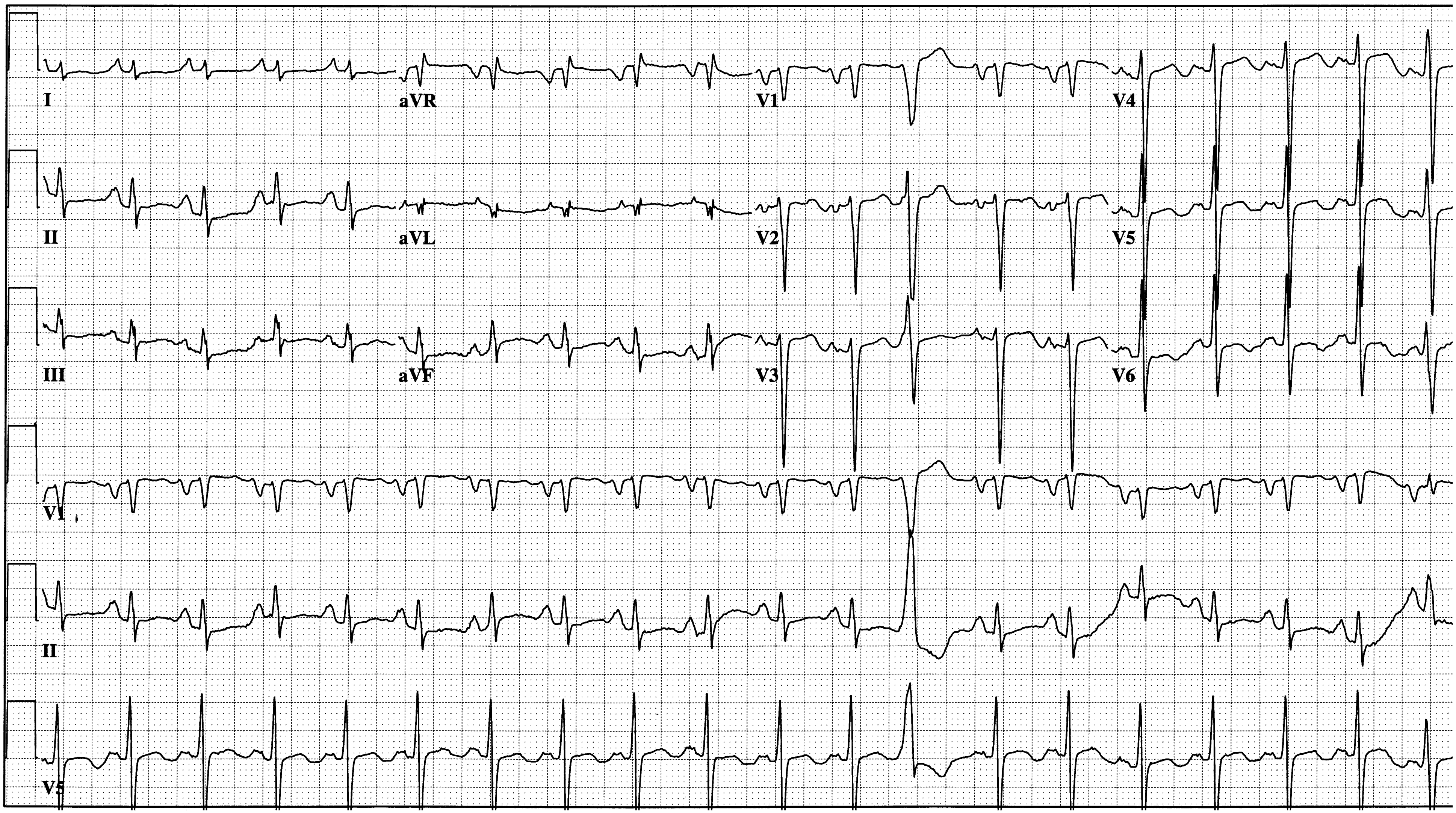
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 19

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

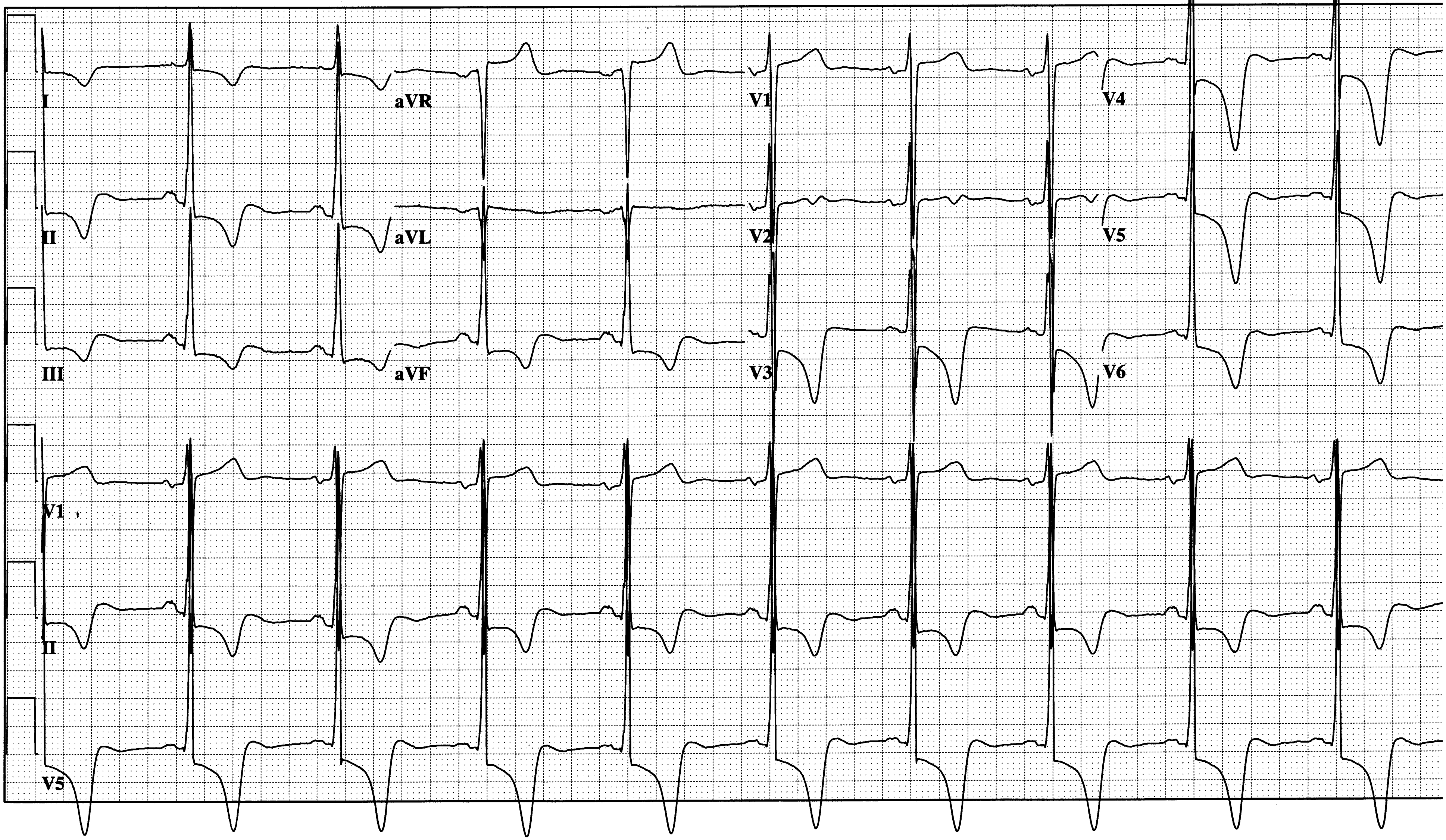
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 20

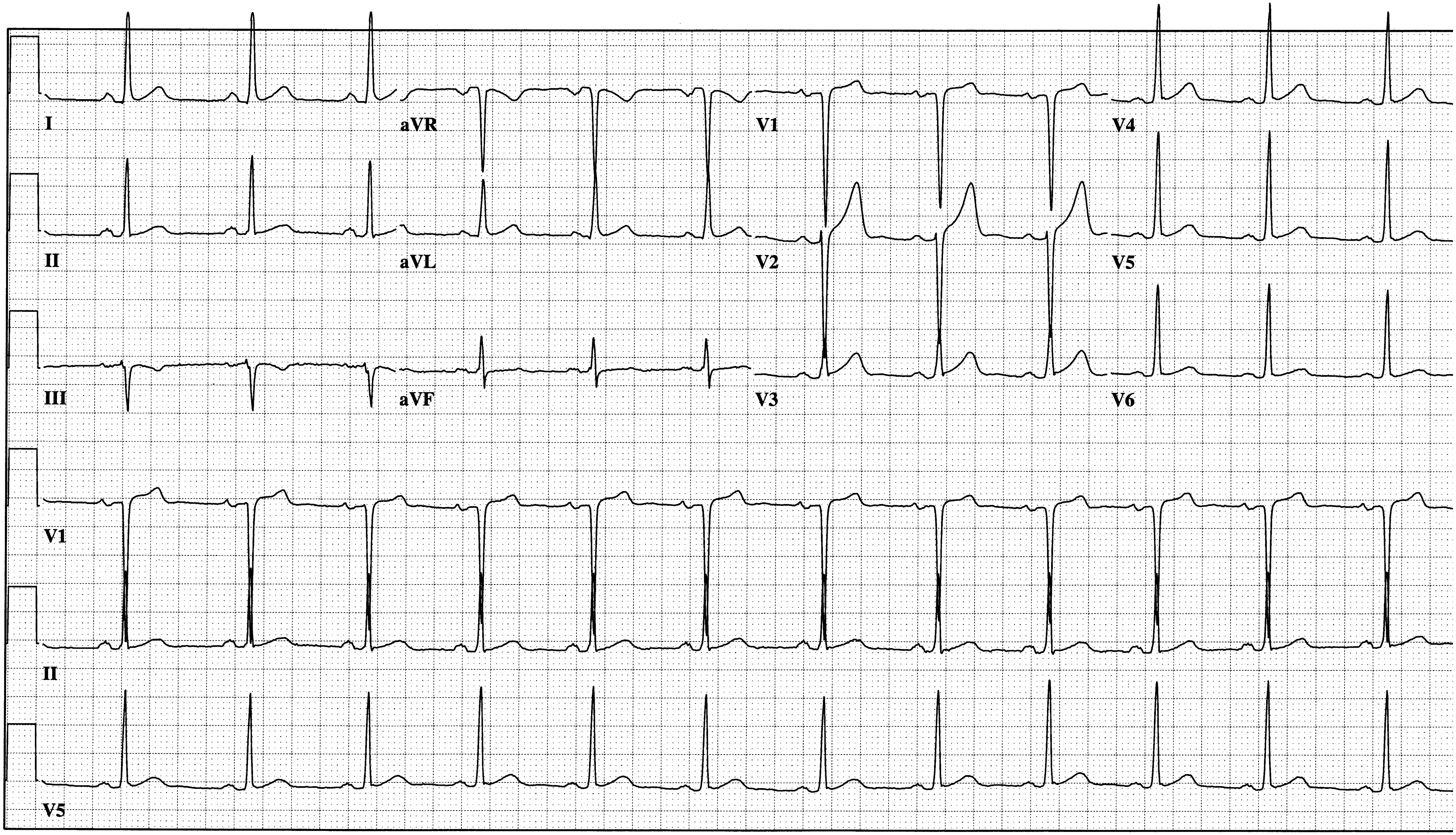
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



Chamber Abnormalities and Intraventricular Conduction Defects

Interpretations of Sample Tracings

ECG 1

Atrial rate: 63
Ventricular rate: 63
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: 130°
  Duration: 140 msec, RBBB, LPFB
  Voltage: Normal
  Morphology: Normal
ST segment:
T wave:
QT interval: 480 msec
U wave:
Diagnosis: Sinus rhythm with an occasional premature atrial complex (PAC), right axis deviation, RBBB, and left posterior fascicular block, (right axis deviation >100°, deep S wave in I and small Q wave in III, and an IVCD)

ECG 2

Atrial rate: 64
Ventricular rate: 64
Rhythm: Sinus rhythm with first degree AV block
P wave: Probable left atrial abnormality
PR interval: 210 msec
QRS complex:
  Axis: –60°
  Duration: 150 msec, RBBB, LAFB
  Voltage: Increased in aVL
  Morphology: Normal
ST segment:
T wave:
QT interval: 440 msec
U wave:
Diagnosis: Sinus rhythm with probable left atrial abnormality (a double-peaked P wave with a duration >130 msec in II), first degree AV block, left axis deviation, RBBB, left anterior fascicular block, (left axis deviation ≥45°, tiny Q waves in I and aVL and an IVCD), and voltage criteria for LVH in aVL

ECG 3

Atrial rate: 52
Ventricular rate: 52
Rhythm: Sinus bradycardia with a first degree AV block
P wave: Normal
PR interval: 270 msec
QRS complex:
  Axis: −50°
  Duration: 105 msec, LAFB
  Voltage: Increased in aVL
  Morphology:
ST segment:
T wave: Normal
QT interval: 450 msec
U wave:
Diagnosis: Sinus bradycardia with a first degree AV block, left axis deviation, and left anterior fascicular block (left axis deviation ≥45°, tiny Q waves in I and aVL, and an IVCD), LVH by voltage criteria in aVL. The diagnosis of left anterior fascicular block is less reliable in the presence of LVH

ECG 4

Atrial rate: 88
Ventricular rate: 88
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 180 msec
QRS complex:
  Axis: 135°
  Duration: 105 msec, LPFB
  Voltage: Normal
  Morphology: Persistent deep S waves across the precordial leads
ST segment: Nonspecific changes
T wave: Normal
QT interval: 400 msec
U wave:
Diagnosis: Sinus rhythm, right axis deviation, and possible left posterior fascicular block (right axis deviation >100°, deep S wave in I and tiny Q wave in III, and an IVCD). The right axis deviation may be due to the presence of chronic lung disease, as evidenced by the persistent deep precordial S waves

ECG 5

Atrial rate: 67
Ventricular rate: 67
Rhythm: Sinus rhythm with sinus arrhythmia
P wave: Normal
PR interval: 150 msec
QRS complex:
  Axis: 90° with RBBB morphology and 60° with normal morphology
  Duration: 160 msec with RBBB morphology and 80 msec with normal morphology
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 420 msec
U wave:
Diagnosis: Sinus rhythm with sinus arrhythmia with RBBB morphology at faster sinus rates. The right bundle is able to conduct normally as long as the heart rate does not exceed a critical value, in which case there is RBBB.

ECG 6

Atrial rate: 56
Ventricular rate: 56
Rhythm: Sinus rhythm with a rate related LBBB
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: 30°
  Duration: 160 msec in LBBB morphology and 105 msec in normal morphology
  Voltage: Normal
  Morphology: Normal
ST segment: Nonspecific changes
T wave: Deep T wave inversion in V_1 to V_4
QT interval: 480 msec
U wave:
Diagnosis: Sinus rhythm with sinus arrhythmia with a rate related LBBB. At faster heart rates, the normal QRS complexes develop a LBBB morphology. There are also deep T wave inversions in V_1 to V_4 suggesting anterior ischemia.

ECG 7

Atrial rate: 58
Ventricular rate: 58
Rhythm: Sinus bradycardia
P wave: Normal

PR interval: 160 msec
QRS complex:
  Axis: 75°
  Duration: 110 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 420 msec
U wave:
Diagnosis: Sinus bradycardia with the morphology of RBBB but insufficient QRS duration for that diagnosis; therefore, this is an incomplete RBBB

ECG 8

Atrial rate: 46
Ventricular rate: 46
Rhythm: Sinus bradycardia with sinus arrhythmia
P wave: Normal
PR interval: 180 msec
QRS complex:
  Axis: –60°
  Duration: 140 msec with a nonspecific IVCD
  Voltage: Normal
  Morphology: Normal
ST segment: Nonspecific changes
T wave: Normal
QT interval: 440 msec
U wave: Prominent U waves in V_1 to V_5
Diagnosis: Sinus bradycardia with significant sinus arrhythmia, left axis deviation, and a nonspecific IVCD (QRS duration >120 msec with neither criteria for RBBB or LBBB)

ECG 9

Atrial rate: 54
Ventricular rate: 54
Rhythm: Sinus bradycardia
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: –45°
  Duration: 140 msec with RBBB
  Voltage: Normal
  Morphology: Q waves in V_1 to V_4
ST segment: Normal
T wave: Nonspecific changes

QT interval: 460 msec
U wave:
Diagnosis: Sinus bradycardia, left axis deviation, and RBBB. The expected R wave of the RSR' configuration in V_1 has been replaced by a Q wave in this patient with a previous anteroseptal MI.

ECG 10

Atrial rate: 73
Ventricular rate: 73
Rhythm: Sinus rhythm with first degree AV block
P wave: Normal
PR interval: 210 msec
QRS complex:
  Axis: 30°
  Duration: 200 msec with LBBB
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval: 440 msec
U wave:
Diagnosis: Sinus rhythm with first degree AV block and LBBB

ECG 11

Atrial rate: 71
Ventricular rate: 71
Rhythm: Sinus rhythm with first degree AV block
P wave: Normal
PR interval: 210 msec
QRS complex:
  Axis: 0°
  Duration: 140 msec
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval: 390 msec
U wave:
Diagnosis: Sinus rhythm with LBBB

ECG 12

Atrial rate: 112
Ventricular rate: 112
Rhythm: Sinus tachycardia
P wave: Right atrial abnormality
PR interval: 140 msec
QRS complex:
  Axis: 90°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 360 msec
U wave:
Diagnosis: Sinus tachycardia with right atrial abnormality

ECG 13

Atrial rate:
Ventricular rate: 37
Rhythm: Atrial fibrillation with a competing junctional pacemaker
P wave:
PR interval:
QRS complex:
  Axis: 45°
  Duration: 90 msec
  Voltage: Low voltage
  Morphology: Possible anteroseptal MI
ST segment: Normal
T wave: Nonspecific changes
QT interval: 580 msec
U wave:
Diagnosis: Atrial fibrillation with a slow ventricular response. All of the longest intervals are identical, consistent with a junctional pacemaker that is activated if the rate is slow enough. There is also extremely low voltage and a possible old anteroseptal MI. This tracing is also consistent with a restrictive cardiomyopathy

ECG 14

Atrial rate: 87
Ventricular rate: 87
Rhythm: Sinus rhythm with first degree AV block
P wave: Left atrial abnormality

PR interval: 280 msec
QRS complex:
Axis: –60°
Duration: 95 msec
Voltage: Normal
Morphology: Normal
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 360 msec
U wave:
Diagnosis: Sinus rhythm with left atrial abnormality, first degree AV block, left axis deviation, and the configuration of RBBB without the duration thereof, and nonspecific ST-T wave changes

ECG 15

Atrial rate: 110
Ventricular rate: 110
Rhythm: Sinus tachycardia
P wave: Right atrial abnormality
PR interval: 180 msec
QRS complex:
Axis: 0°
Duration: 80 msec
Voltage: Normal
Morphology: Normal
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 320 msec
U wave:
Diagnosis: Sinus tachycardia with right atrial abnormality and nonspecific ST-T wave changes

ECG 16

Atrial rate: 128
Ventricular rate: 128
Rhythm: Sinus tachycardia
P wave: Normal
PR interval: 130 msec
QRS complex:
Axis: –75°
Duration: 140 msec, RBBB, LAFB
Voltage: Increased in aVL and in the precordial leads
Morphology: Possible old septal MI
ST segment:

T wave:
QT interval: 340 msec
U wave:
Diagnosis: Sinus tachycardia with left axis deviation, RBBB, left anterior fascicular block (left axis deviation ≥45°, tiny Q waves in I and aVL and an IVCD), LVH by voltage criteria

ECG 17

Atrial rate: 106
Ventricular rate: 106
Rhythm: Sinus tachycardia
P wave: Right atrial abnormality
PR interval: 140 msec
QRS complex:
  Axis: 100°
  Duration: 80 msec
  Voltage: Suggestive of RVH
  Morphology: Tall R wave in V_1
ST segment: Normal
T wave: Normal
QT interval: 300 msec
U wave:
Diagnosis: Sinus tachycardia with right atrial abnormality, right axis deviation, and a tall R wave in V_1, all suggesting RVH in a patient with known severe pulmonary HTN

ECG 18

Atrial rate: 120
Ventricular rate: 120
Rhythm: Sinus tachycardia
P wave: Biatrial abnormality
PR interval: 160 msec
QRS complex:
  Axis: Indeterminate
  Duration: 90 msec
  Voltage: Normal
  Morphology: Persistent deep S waves across the precordial leads
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 320 msec
U wave:
Diagnosis: Sinus tachycardia with biatrial abnormality, an occasional PVC, and persistent deep S waves across the precordial leads suggesting pulmonary disease

ECG 19

Atrial rate: 58
Ventricular rate: 58
Rhythm: Sinus bradycardia
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: 60°
  Duration: 100 msec
  Voltage: Extremely high in V_4 to V_6
  Morphology: Normal
ST segment: Diffuse changes
T wave: Diffuse deep T wave inversion
QT interval: 600 msec
U wave:
Diagnosis: Sinus bradycardia with LVH by voltage criteria and significant repolarization abnormalities

ECG 20

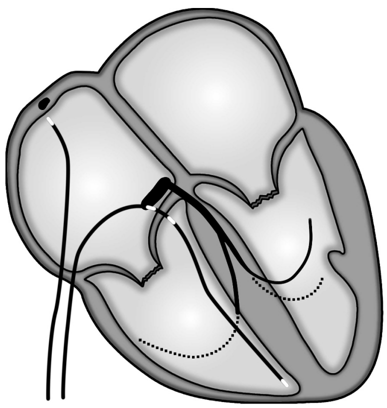
Atrial rate: 75
Ventricular rate: 75
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: 30°
  Duration: 80 msec
  Voltage: Increased in I
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 360 msec
U wave:
Diagnosis: Sinus rhythm with voltage criteria for LVH in I

Day 3

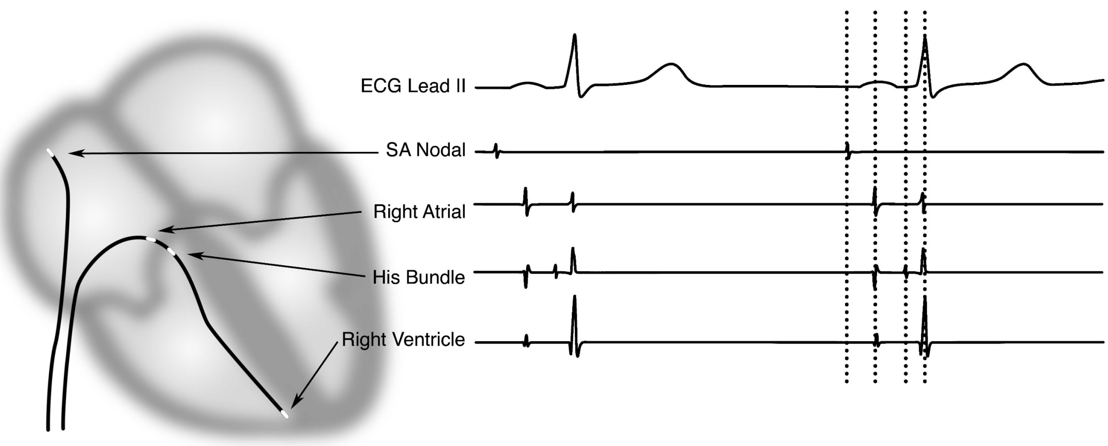
SA and AV Nodal Conduction Abnormalities

I. Intracardiac electrograms

A. Conduction disturbances in the surface ECG have their genesis in specific locations in the conduction system.

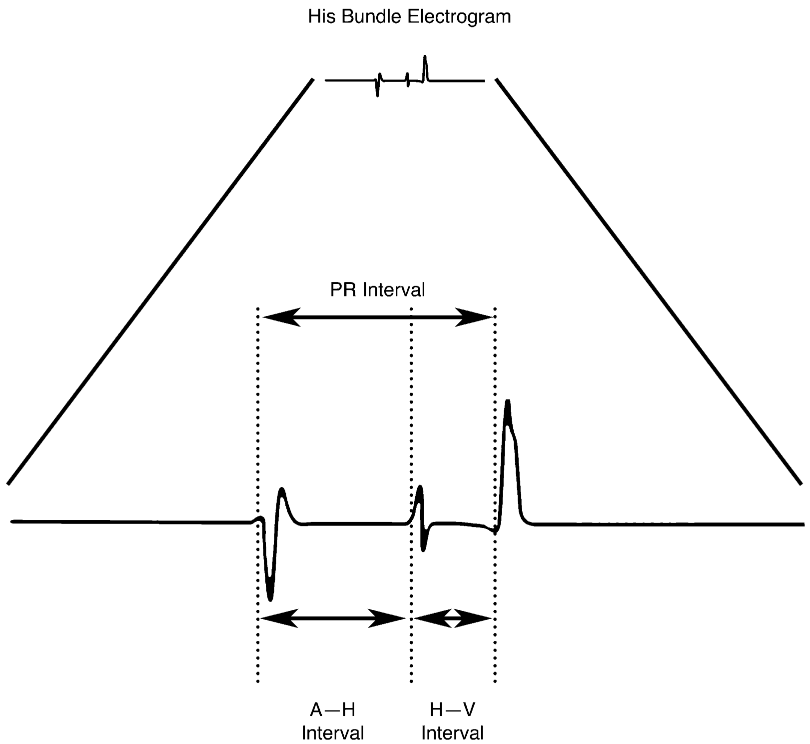


Simultaneous Lead II and intracardiac Leads from the SA nodal, RA, His bundle, and the RV. Note the SA impulse which precedes the P wave, the large P waves from the RA, the His bundle spike, and the large QRS complex from the RV. The paper speed is 100 mm/sec.



B. Surface ECG disturbances are more clearly appreciated by concomitant analysis of the intracardiac electrogram.

C. Components of the intracardiac electrogram
   1. Sinoartrial (SA) node
      a. There is no surface ECG representation of SA nodal depolarization; a recurrent, normal axis P wave *implies* that the SA node is responsible.
      b. Careful recordings from a tiny area in the upper right portion of right atrium have demonstrated SA nodal activity preceding atrial depolarization.
   2. Atria
      a. Atrial depolarization produces the P wave on the surface ECG.
      b. The P wave axis is demonstrative of the direction of atrial depolarization.
   3. Atrioventricular (AV) node
      a. The AV node is responsible for most of the delay between the P wave and the QRS complex.
      b. On the intracardiac electrogram, the delay in the AV node is represented by the P wave to His bundle spike interval (the A—H interval).
      c. Disturbances of AV nodal conduction result in prolongation of the A—H interval.



The PR interval is the sum of the A—H interval (which represents the time required to traverse the atrium and the AV node) and the H—V interval (which represents the time required to traverse the His bundle)

4. His bundle
   a. There is no surface representation of His bundle activation; it is *implied* by a succeeding QRS complex.
   b. On the intracardiac electrogram, careful positioning of an electrode cam demonstrate a small deflection coincident with the activation of the His bundle.
   c. The time between the His bundle spike and the QRS complex is the H—V interval.
   d. The sum of A—H and H—V intervals equals the PR interval.
5. Bundle branches
   a. Depolarization of the right and left bundles produce the QRS complex on the surface ECG.
   b. Defects of bundle branch conduction were discussed on Day 2.

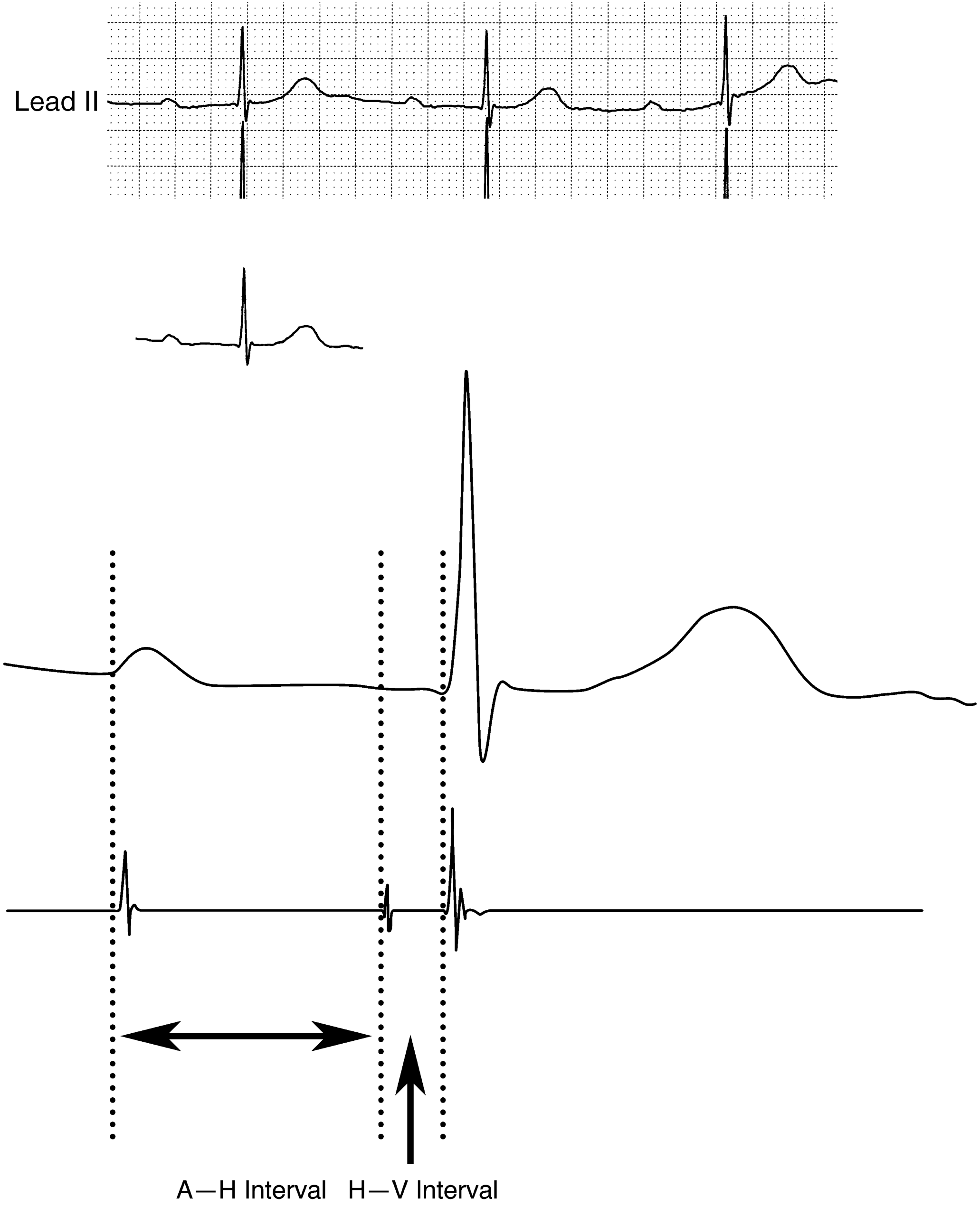
II. AV conduction abnormalities

A. First degree AV block (Day 3-01) (Day 3-02)
   1. In first degree AV block, the PR interval > 200 msec.
   2. The PR interval is dependent on heart rate, so that at very slow rates, a PR interval > 200 may be normal.
   3. First degree AV block is almost always due to a prolongation of the A—H interval.

B. Second degree AV block
   1. Type I (Wenckebach) (Day 3-03) (Day 3-04)
      a. In second degree AV block type I, there is progressive prolongation of the PR interval until there is a dropped QRS complex.
      b. The Wenckebach phenomenon usually produces group beating of the QRS complexes.
      c. In the His bundle electrogram, there is progressive prolongation of the A—H interval until there is no His spike produced.
      d. The H—V interval is usually normal.
   2. Second degree AV block type II (Day 3-05) (Day 3-06)
      a. In second degree AV block type II, there are regular P waves with an occasional loss of the QRS complex.
      b. The PR interval does not change before the conducted beats.
      c. On the His bundle electrogram, this type of block is usually associated with an intermittent failure of H—V conduction.

C. Third degree AV block (Day 3-07) (Day 3-8)
   1. In third degree AV block, there is complete failure of conduction from the atria to the ventricles.
   2. The atrial rate is always faster than the ventricular rate.
   3. The escape rhythm may arise from the junctional area, in which case its rate will typically be 40–60, or it may arise from a ventricular focus with a rate of 20–40.

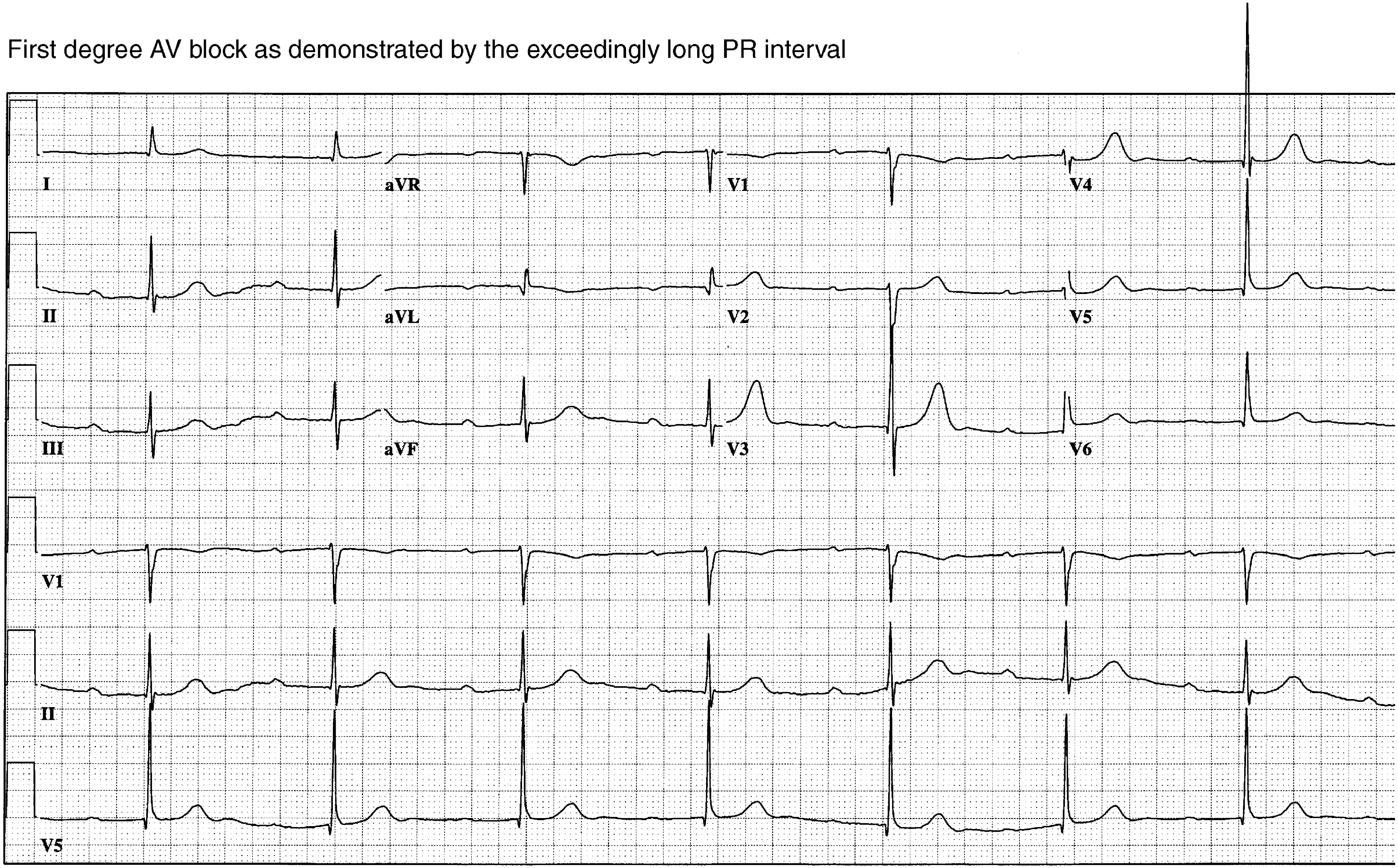
DAY 3-01



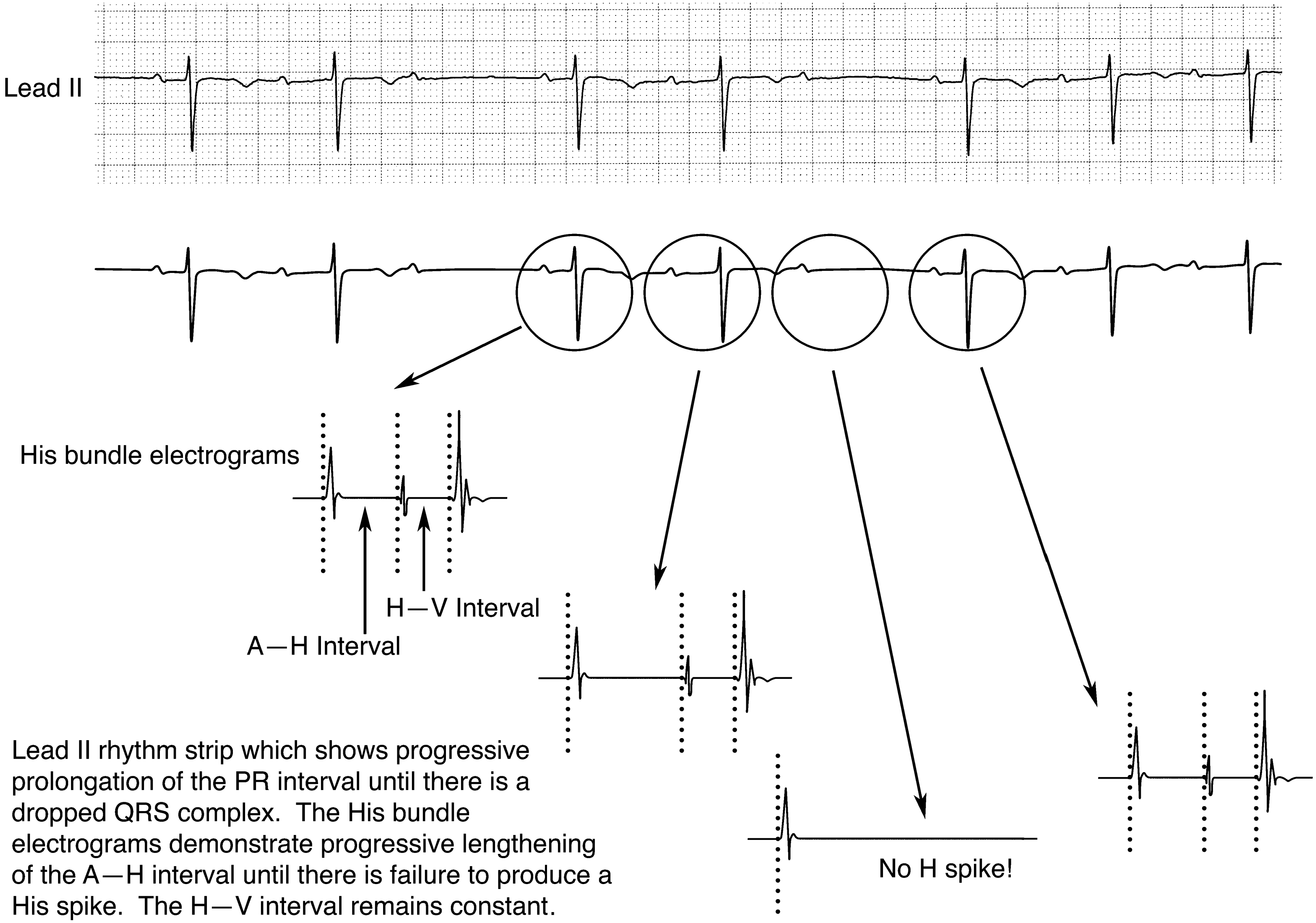
The Lead II ECG shows sinus rhythm with a very long PR interval of over 400 msec, demonstrating first degree AV block. The His bundle electrogram shows prolongation of the A—H interval with a normal H—V interval. This finding is typical of delay in the AV node itself.

DAY 3-02

First degree AV block as demonstrated by the exceedingly long PR interval



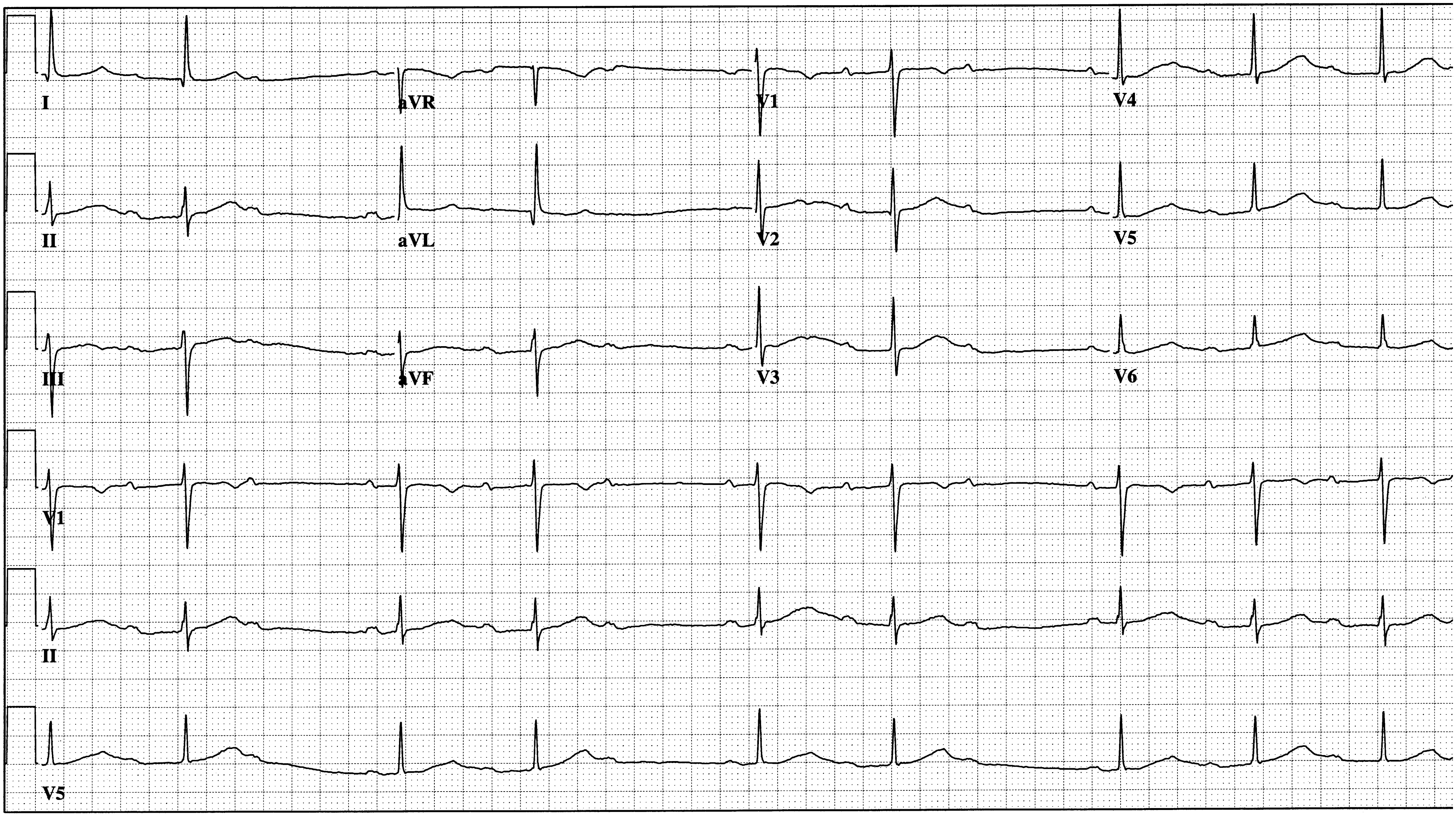
DAY 3-03

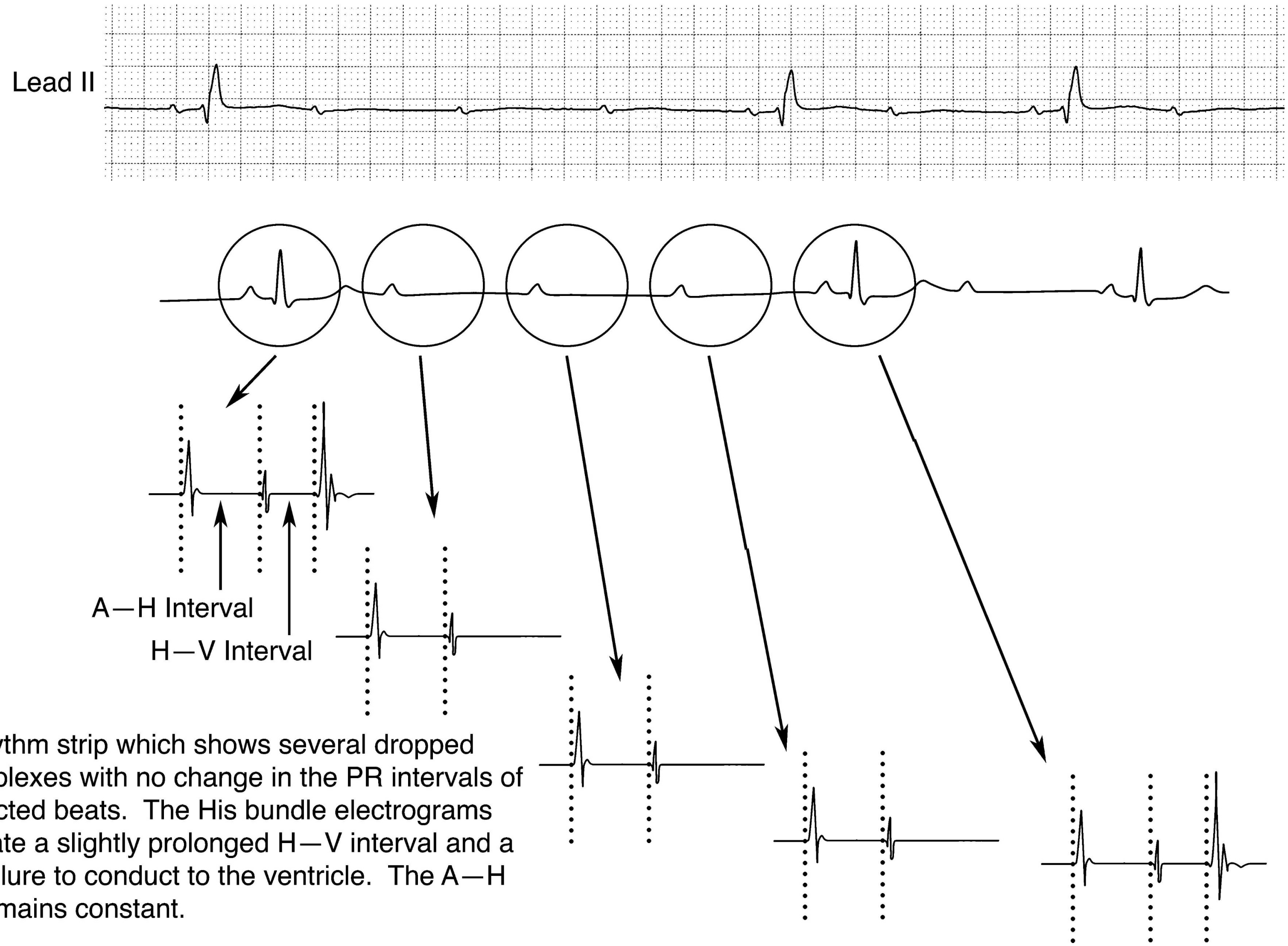


Lead II rhythm strip which shows progressive prolongation of the PR interval until there is a dropped QRS complex. The His bundle electrograms demonstrate progressive lengthening of the A—H interval until there is failure to produce a His spike. The H—V interval remains constant.

DAY 3-04

Second degree AV block type I as demonstrated by progressive prolongation of the PR interval until there is a a dropped QRS complex. There is always one more P wave than QRS complex in each group.

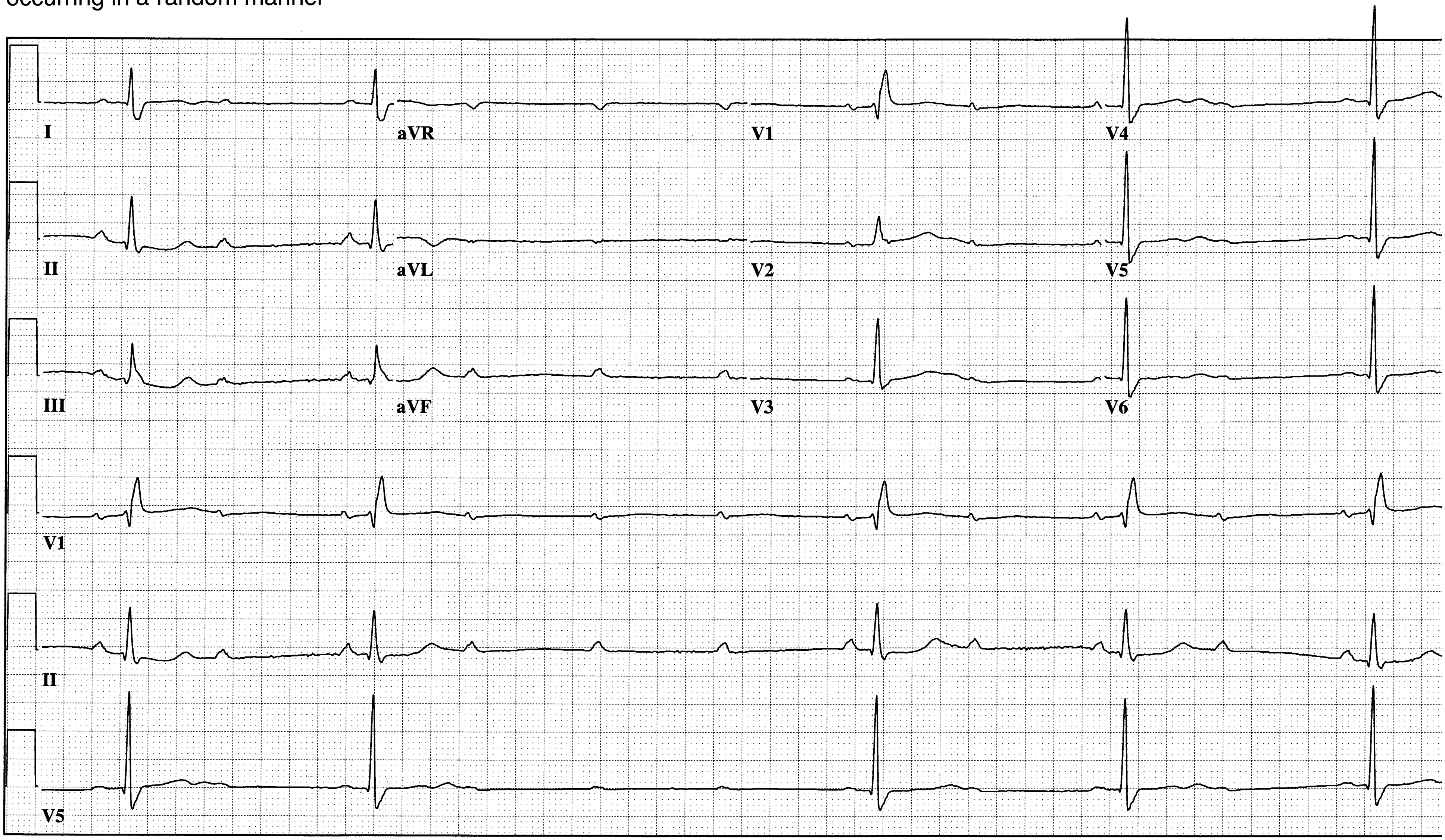




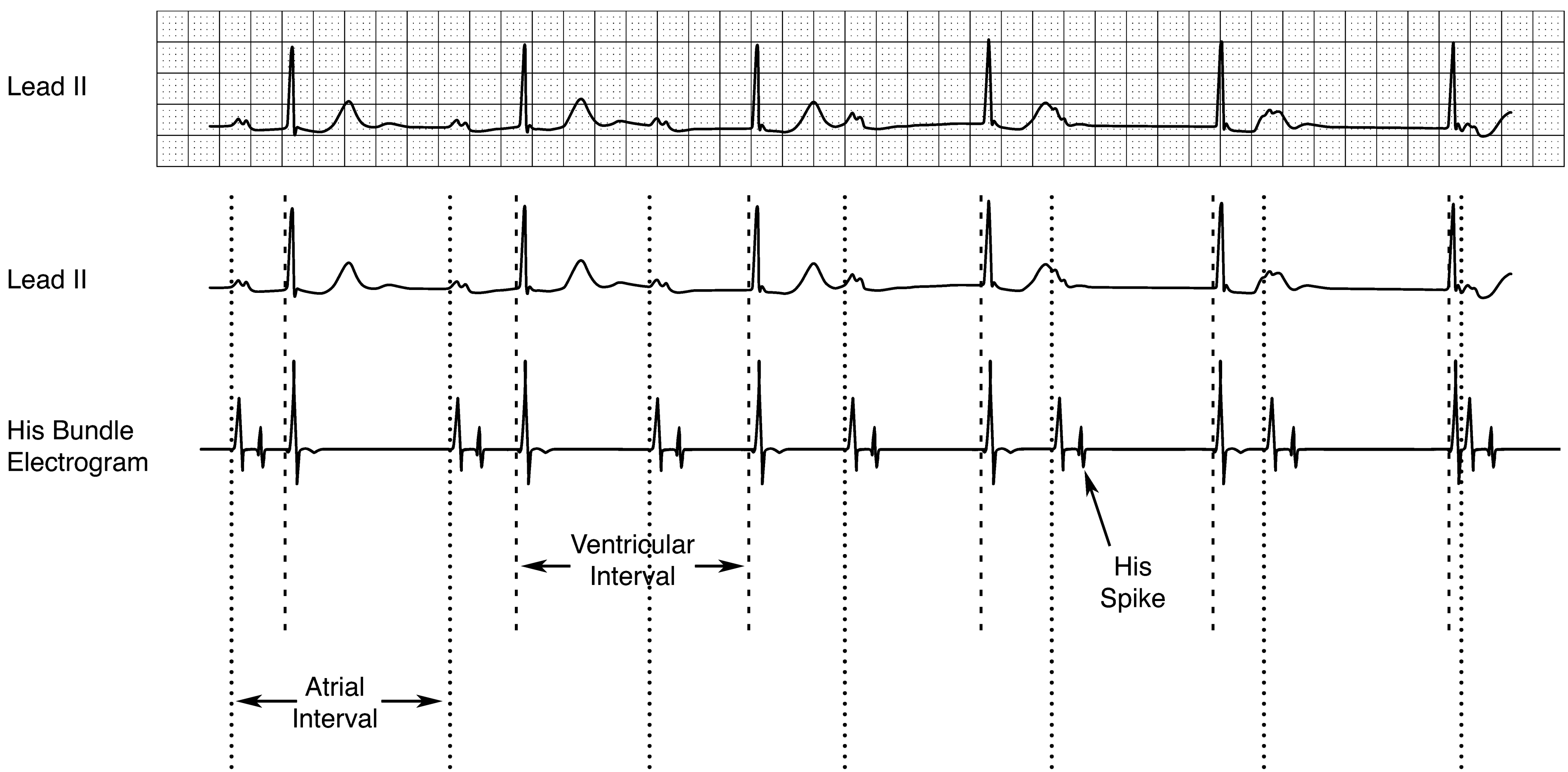
Lead II rhythm strip which shows several dropped QRS complexes with no change in the PR intervals of the conducted beats. The His bundle electrograms demonstrate a slightly prolonged H—V interval and a sudden failure to conduct to the ventricle. The A—H interval remains constant.

DAY 3-06

Second degree AV block type II as demonstrated by several P waves without succeeding QRS complexes occurring in a random manner



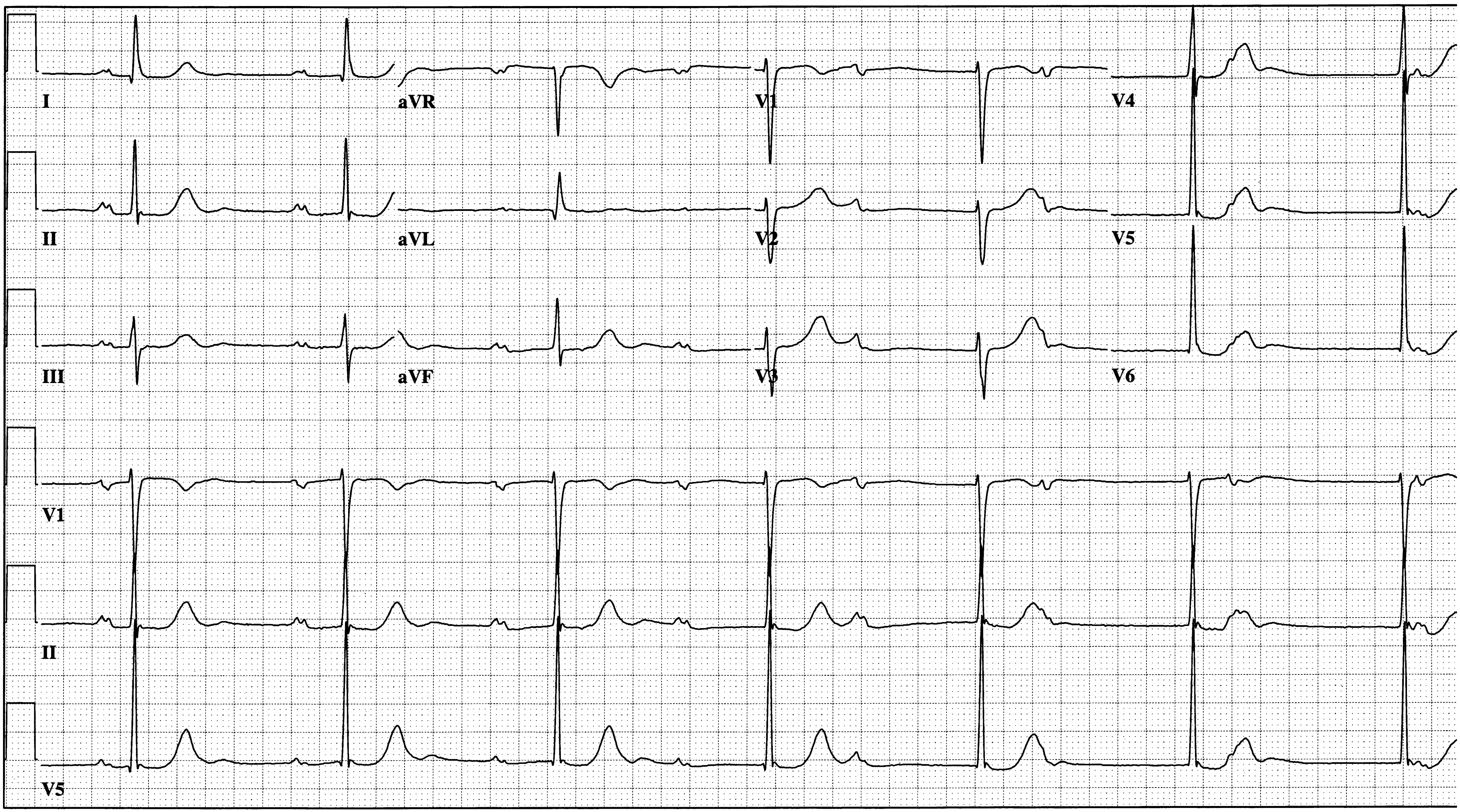
DAY 3-07



Surface Lead II and His bundle electrograms in third degree AV block. Note the independent atrial (dotted lines) and ventricular (dashed lines) rhythms. In the His bundle electrogram, a His spike follows each atrial impulse, and the A—H interval is normal. However, there is no succeeding ventricular depolarization, so this represents a complete failure of H—V conduction.

DAY 3-08

Third degree AV block as demonstrated by simultaneous sinus and junctional escape rhythms with no relation to each other. This is an example of AV dissociation.



4. Junctional escape rhythms have a narrow QRS complex (unless there is an accompanying bundle branch block), but ventricular rhythms will be wide (QRS > 120 msec).
5. Third degree block is one form of A-V dissociation (see later in this chapter).
6. There may be slight variation in the P-P intervals, with the P waves which surround a QRS complex being slightly closer together than those which do not (ventriculophasic sinus arrhythmia).

D. Summary of AV block
1. First degree AV block is usually caused by a prolongation of the A—H interval.
2. Second degree AV block type I (Wenckebach) is caused by progressive prolongation of the A—H interval.
3. Second degree AV block type II is usually caused by an intermittent failure of H—V conduction.
4. Third degree AV block is usually caused by a complete failure of H—V conduction.
5. In general, A—H prolongation is a benign clinical event, while abnormalities of H—V conduction represent serious clinical situations that usually require permanent pacing.

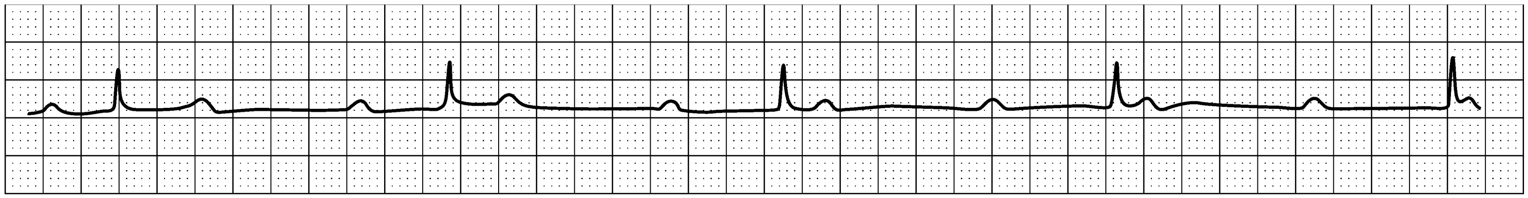
First degree AV block Second degree AV block type I	Usually caused by delay of conduction in the AV node, resulting in A—H prolongation. This is typically a benign clinical situation.
Second degree AV block type II Third degree AV block	Usually caused by a block distal to the AV node, resulting in H—V conduction failure. This is usually a clinically unstable situation which frequently requires permanent pacing.

III. AV dissociation

A. AV dissociation is present when there are independent atrial and ventricular rhythms.

B. Types of AV dissociation
1. By default
   a. In this case, there is a failure of conduction from a higher pacemaker, so that a lower pacemaker takes over
   b. Third degree block is the principle example of this form of AV dissociation.
2. By usurpation (Day 3-9)
   a. In this case, a lower pacemaker speeds up and usurps control from the higher pacemaker by virtue of being faster.
   b. Ventricular tachycardia (70% of which has AV dissociation) is an example of this form.

DAY 3-09



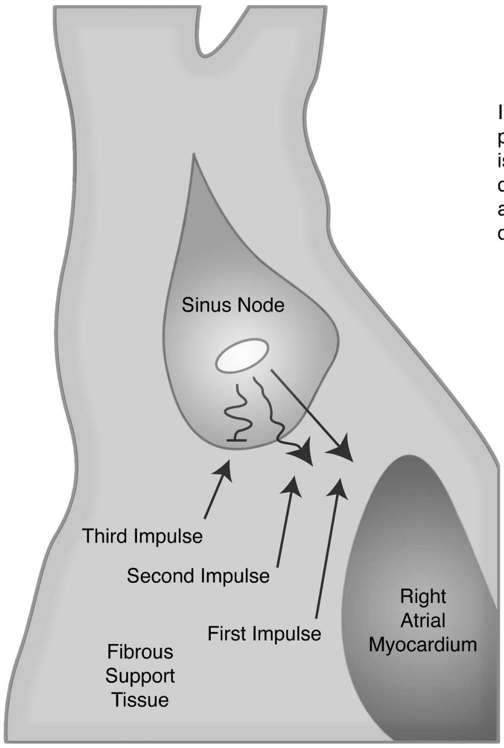
AV dissociation by default (third degree AV block)

AV dissociation by usurpation (ventricular tachycardia). The ventricular rate is about 130, and the atrial rate (indicated by the dashed lines) is about 85.

IV. SA block

A. The four types of conduction abnormalities associated with the AV node also exist for the SA node; however first degree, second degree type II, and third degree SA block cannot be identified on the surface ECG. (Day 3-10) (Day 3-11) (Day 3-12)

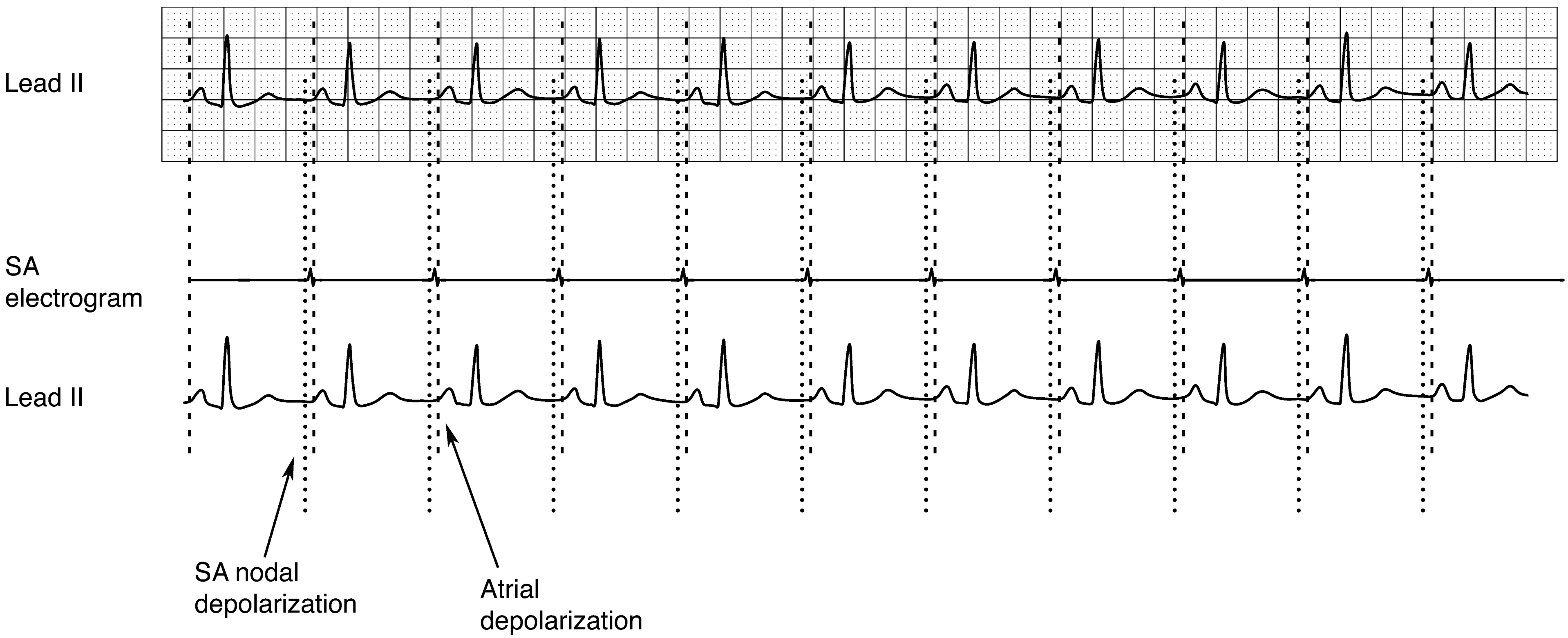
B. Second degree SA block type I produces an identifiable pattern of group beating on the ECG, with P waves of the same morphology and unchanging PR intervals. (Day 3-13) (Day 3-14)



In this cross section of the SA node, there is progressive delay of the SA nodal impulse until there is a failure to "get out of" the node. This is typically due to excessive refractoriness of the fibrous tissue around the node. This situation produces varying degrees of SA exit block.

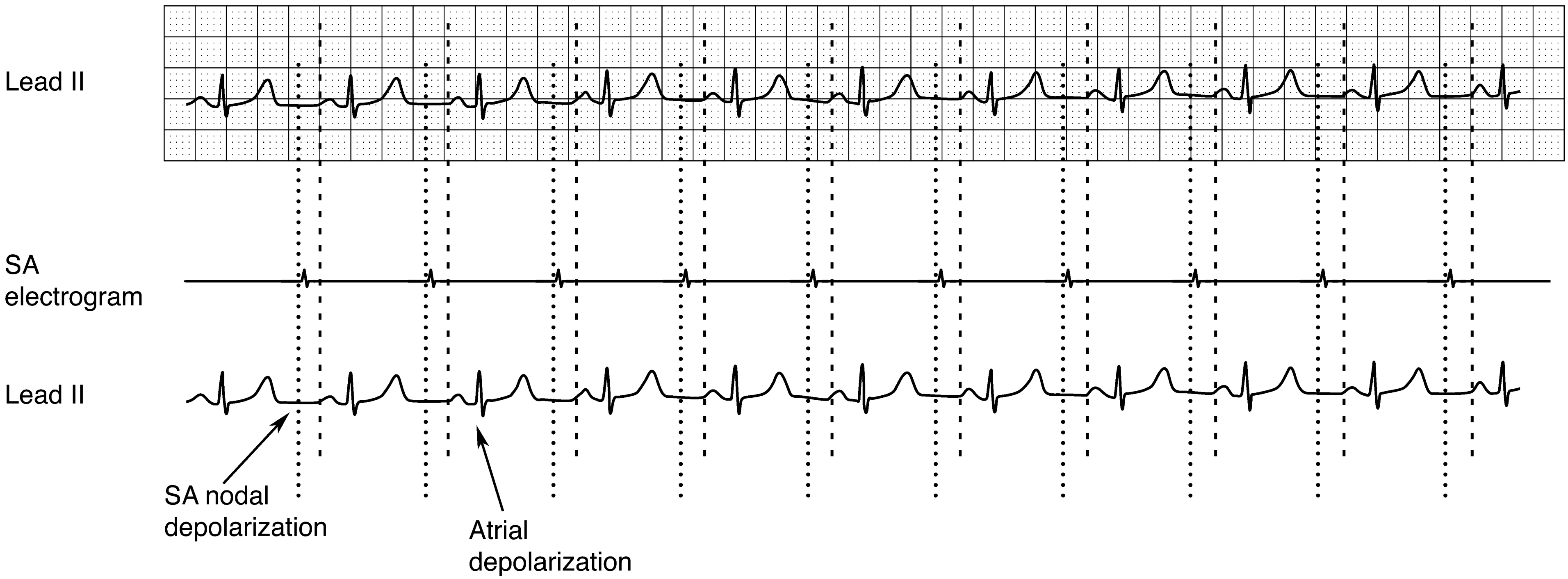
V. Group beating of QRS complexes and examples of AV and SA nodal block. (Day 3-15) (Day 3-16)(Day 3-17) (Day 3-18) (Day 3-19) (Day 3-20) (Day 3-21) (Day 3-22) (Day 3-23)

DAY 3-10



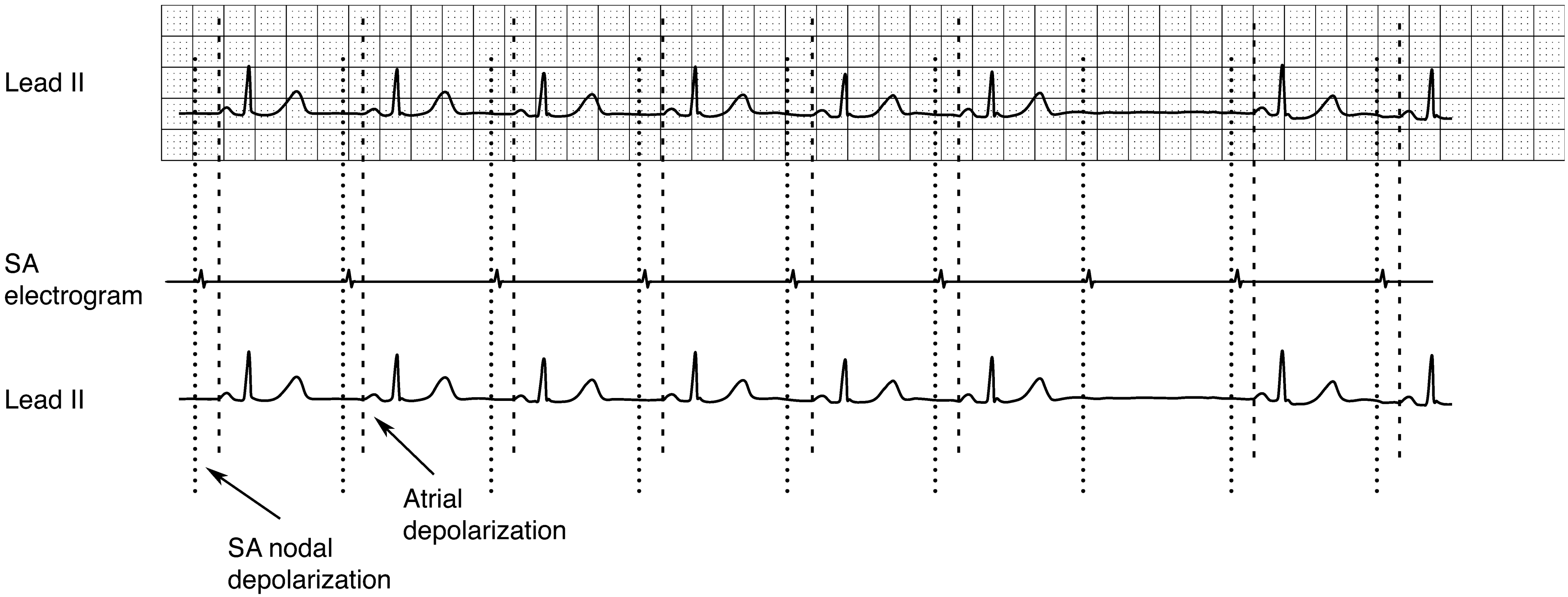
Normal SA nodal conduction. Each SA impulse is followed by atrial depolarization.

DAY 3-11



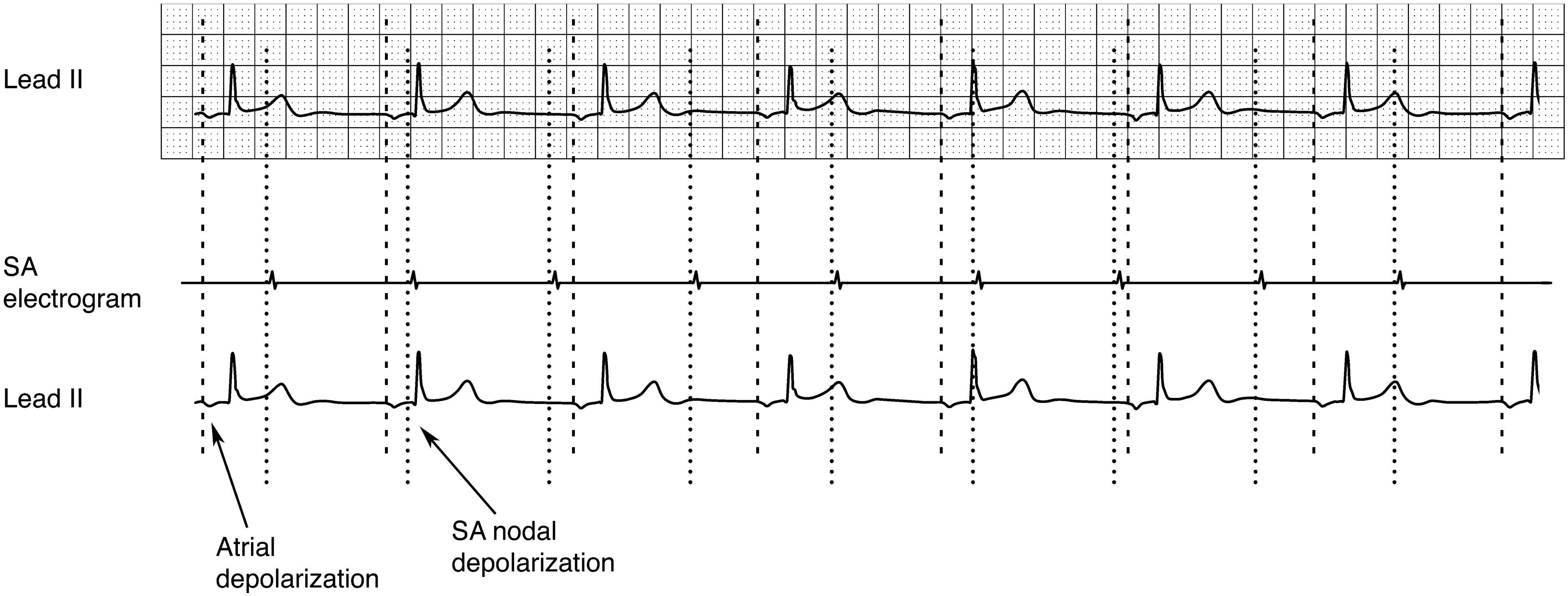
First degree SA nodal block. Each SA impulse is followed by atrial depolarization, but the SA impulse to P wave interval is increased. This situation is not detectable on the surface ECG.

DAY 3-12



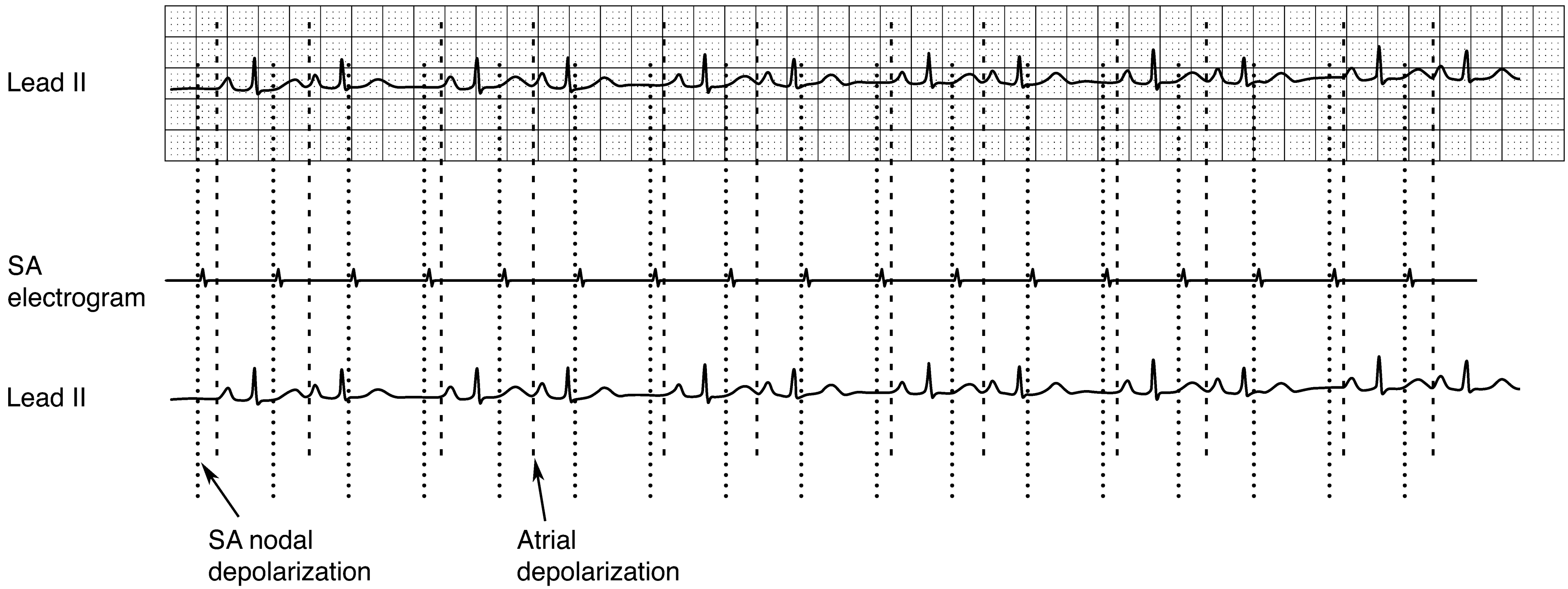
Second degree SA block type II. There are regular SA nodal depolarizations in the SA electrogram, but there is an occasional failure to depolarize the atrium and hence no P wave. The mechanism of this situation cannot be determined on the surface ECG.

DAY 3-13



Third degree SA block. There are regular SA nodal depolarizations in the SA electrogram, but there is no relation ship to the atrial activity. In this case, an ectopic atrial bradycardia (note the inverted P waves in Lead II) has occurred by default. The mechanism of this situation cannot be determined on the surface ECG.

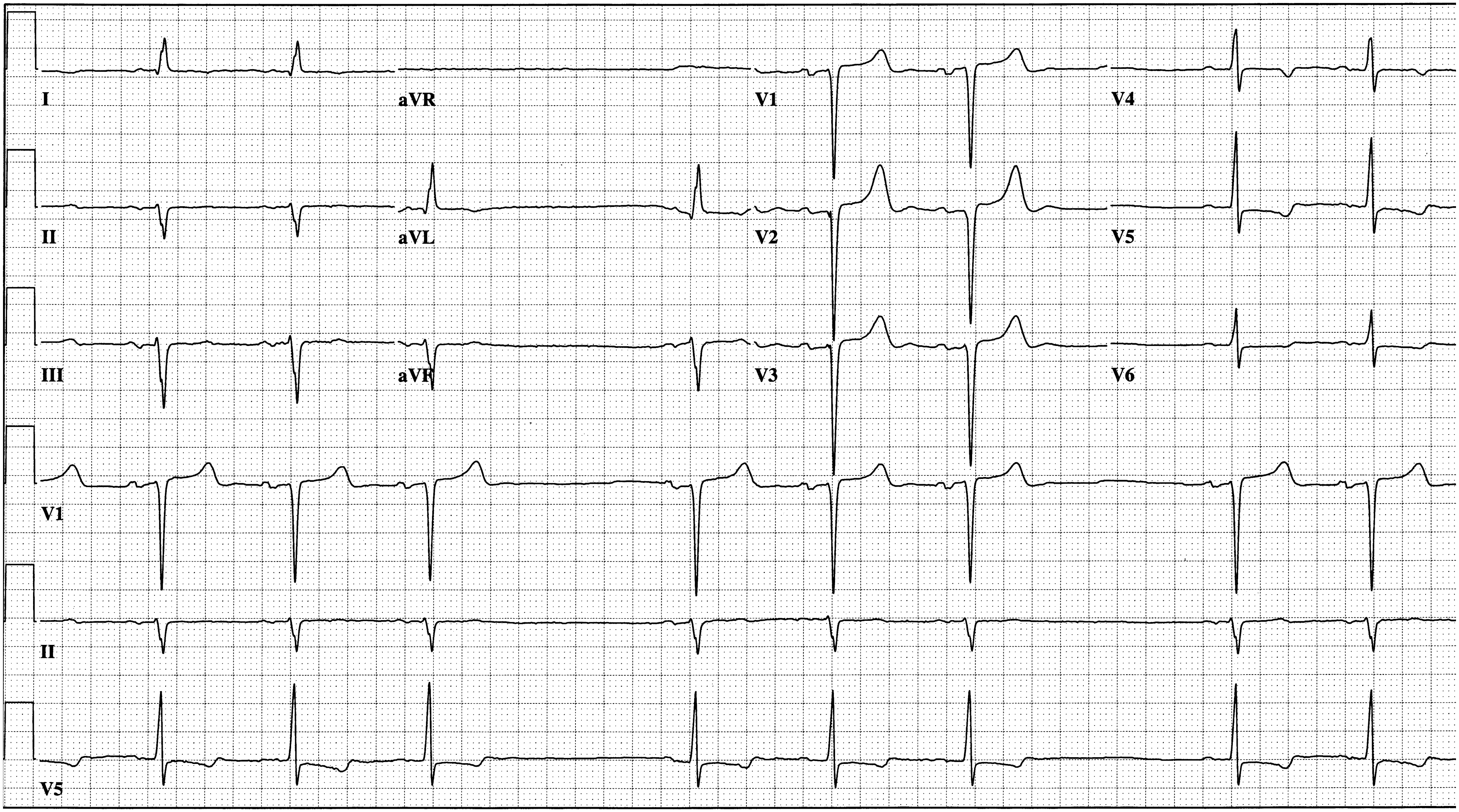
DAY 3-14

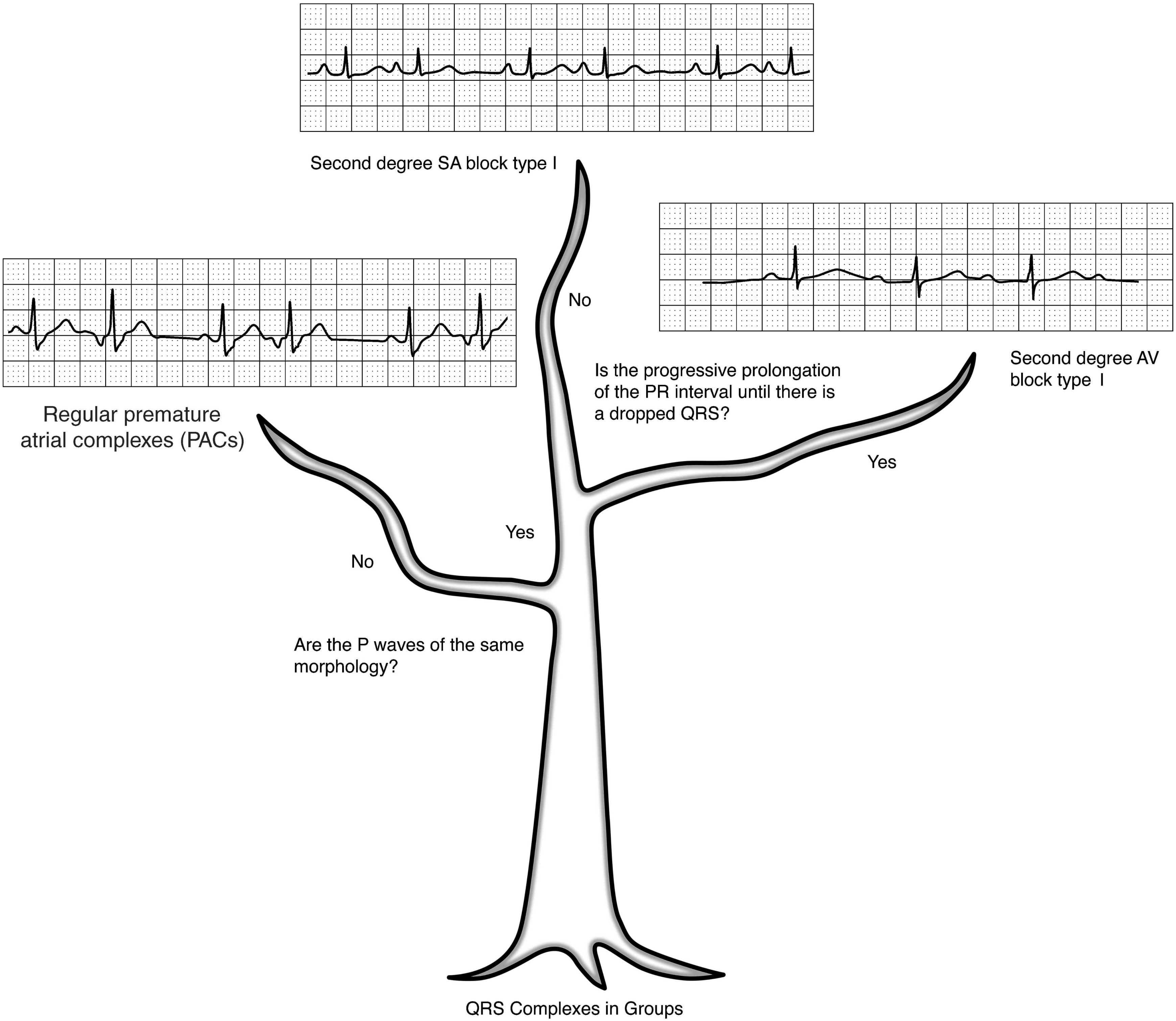


Second degree SA block type I. There are regular SA nodal depolarizations in the SA electrogram, but there is a progressive lengthening in the SA nodal to atrial interval until there is a dropped P wave. The PR interval is normal. This situation is recognizable on the surface ECG by the group beating of QRS complexes, identical P wave morphology, and unchanging PR intervals. This is the only one of the SA block conditions which can be diagnosed on the surface ECG.

DAY 3-15

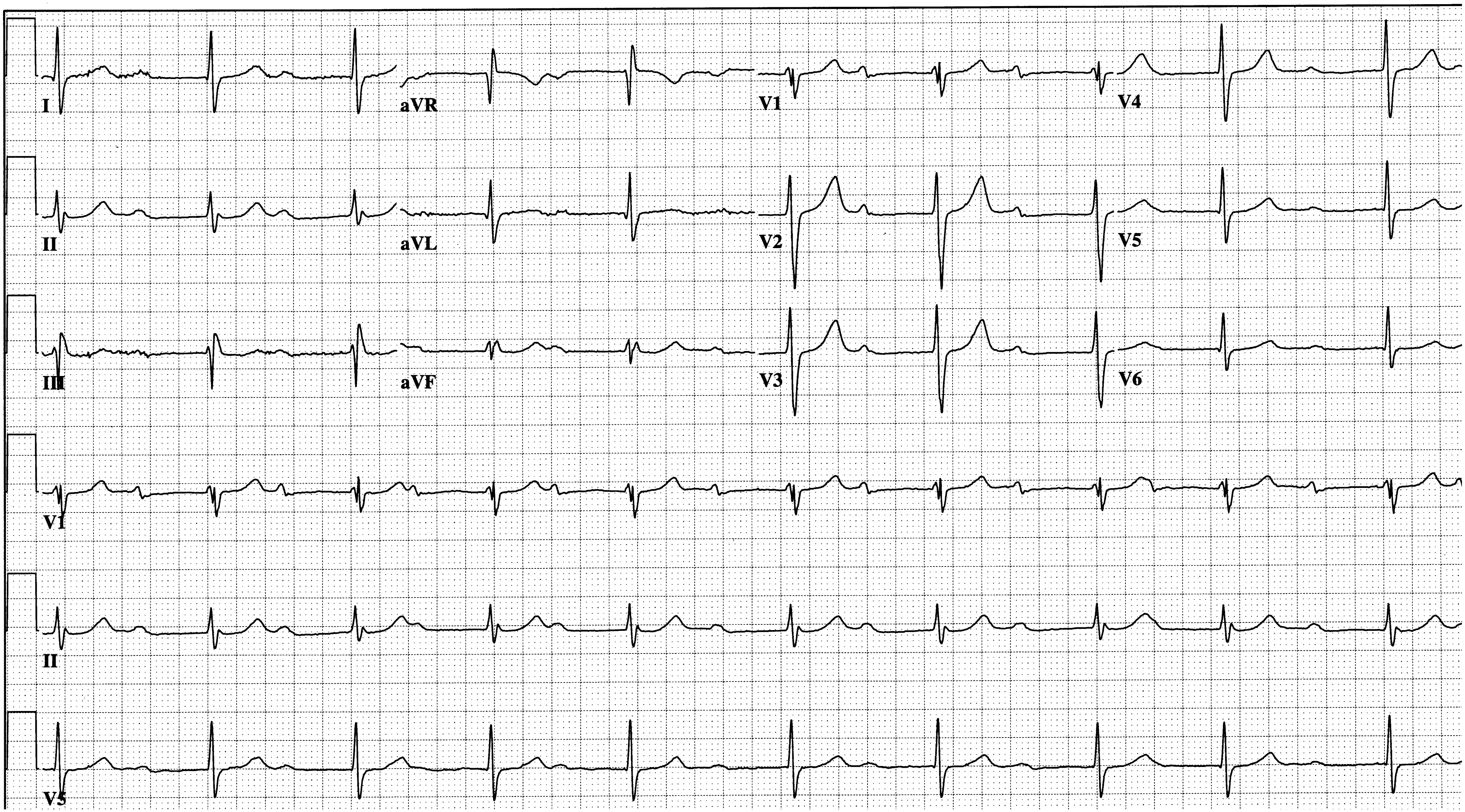
Second degree SA block type I as indicated by group beating of QRS complexes, identical P waves and PR intervals, and no nonconducted P waves. This is the only one of the four forms of SA block which can be diagnosed on a surface ECG.




Second degree SA block type I
Regular premature
atrial complexes (PACs)
No
Second degree AV
block type I
Is the progressive prolongation
of the PR interval until there is
a dropped QRS?
Yes
Yes
No
Are the P waves of the same
morphology?
QRS Complexes in Groups

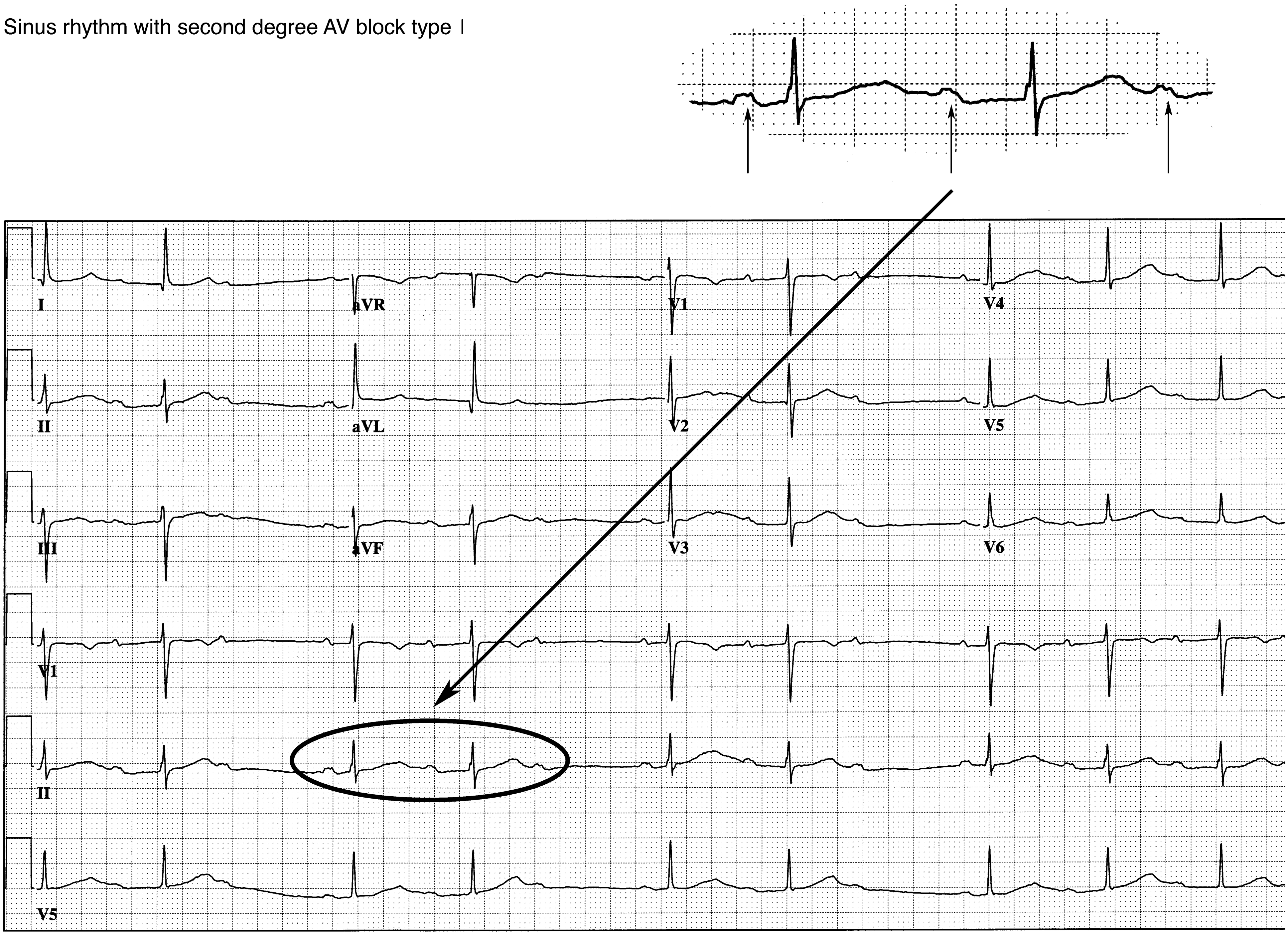
DAY 3-17

Sinus rhythm with a long first degree AV block



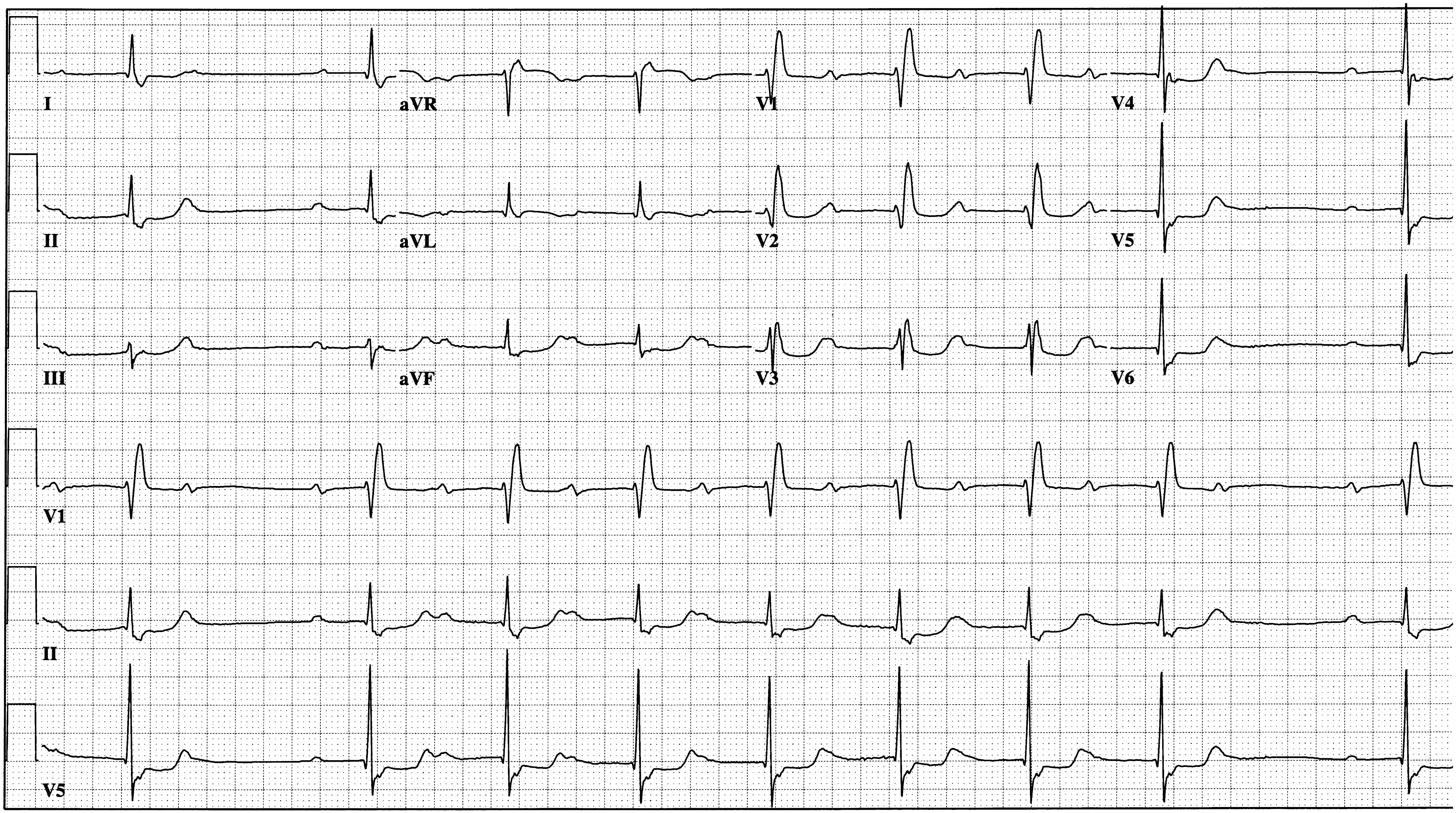
DAY 3-18

Sinus rhythm with second degree AV block type I



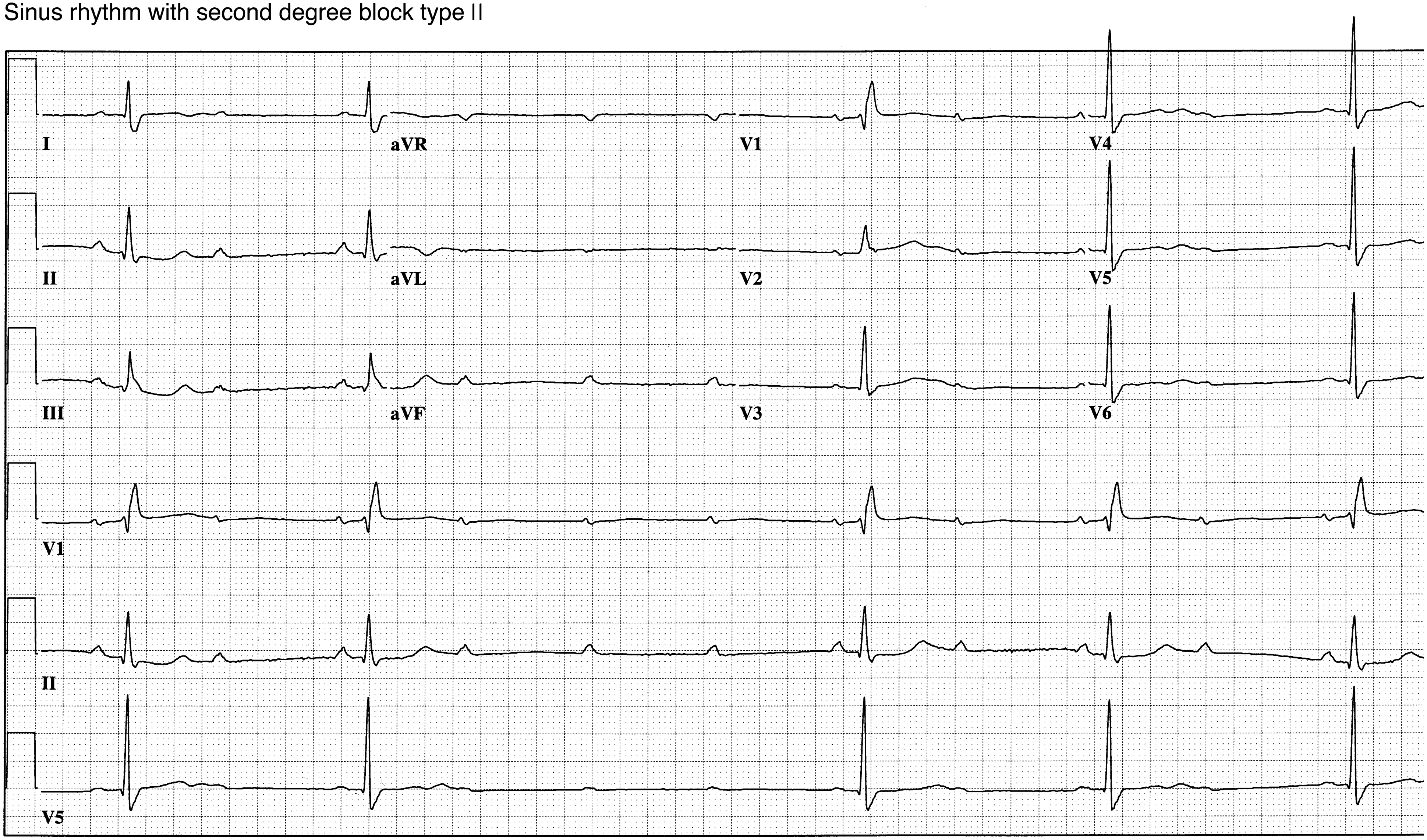
DAY 3-19

Sinus rhythm with second degree AV block type I



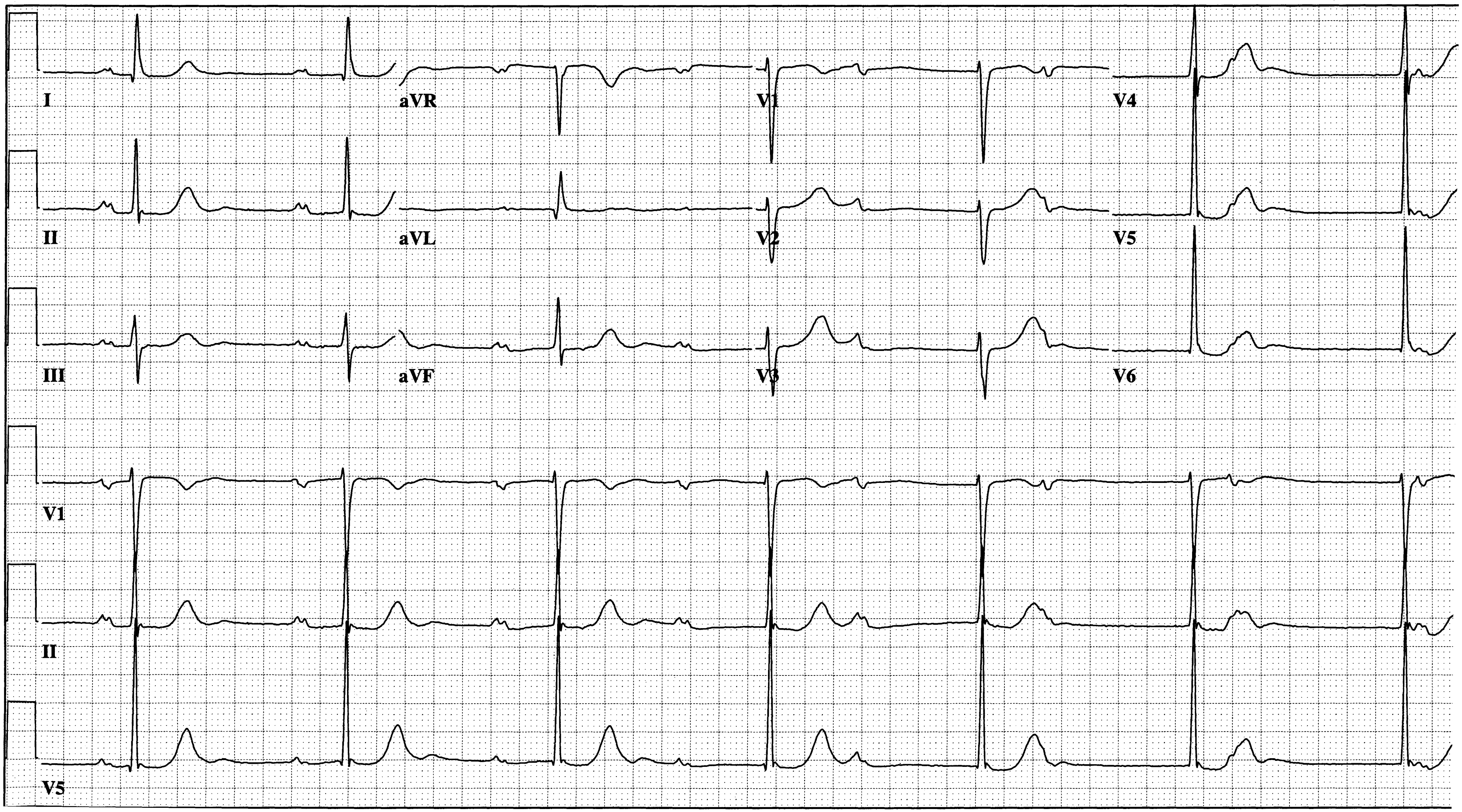
DAY 3-20

Sinus rhythm with second degree block type II



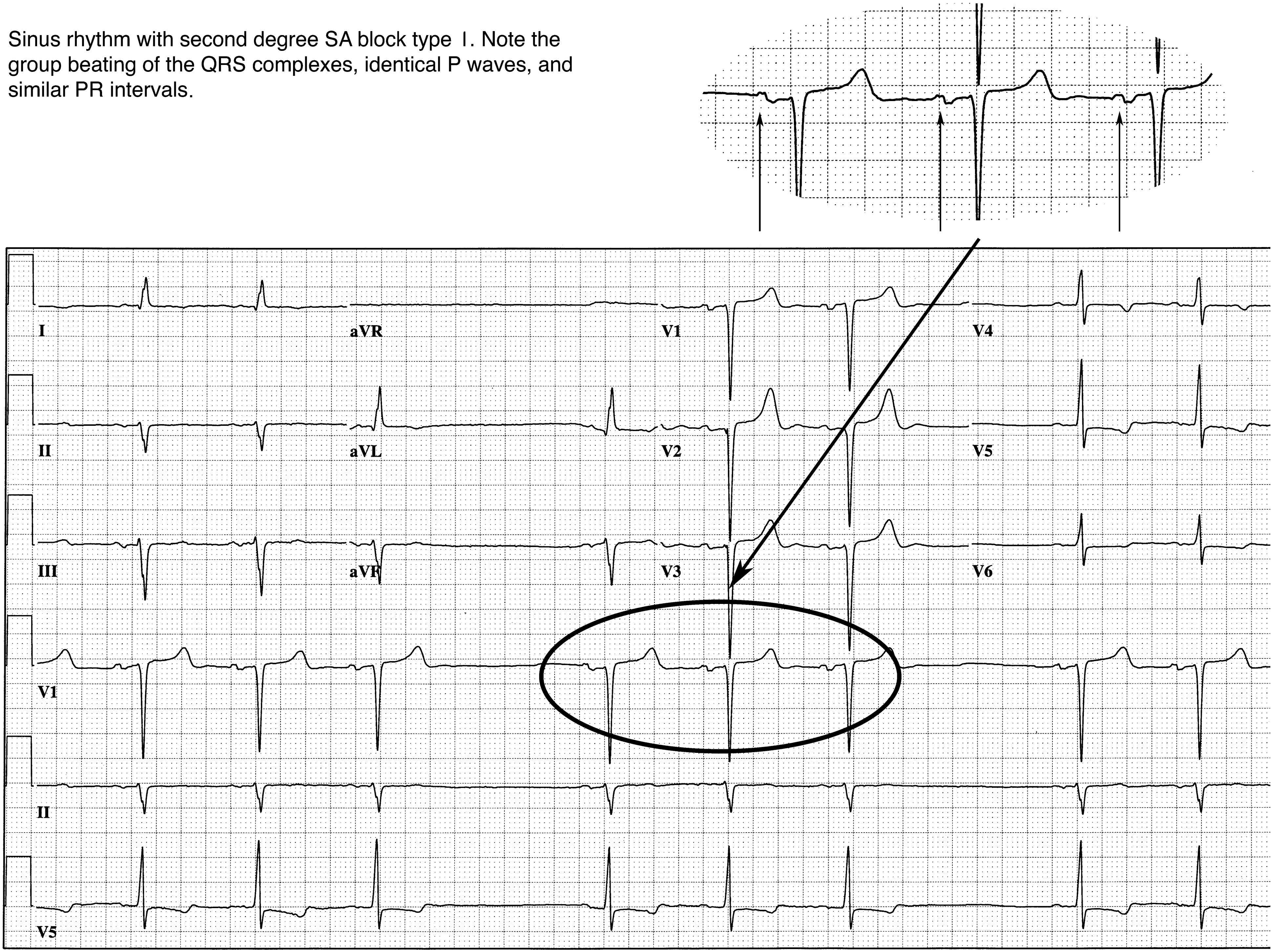
DAY 3-21

Sinus rhythm, third degree AV block, and junctional escape rhythm



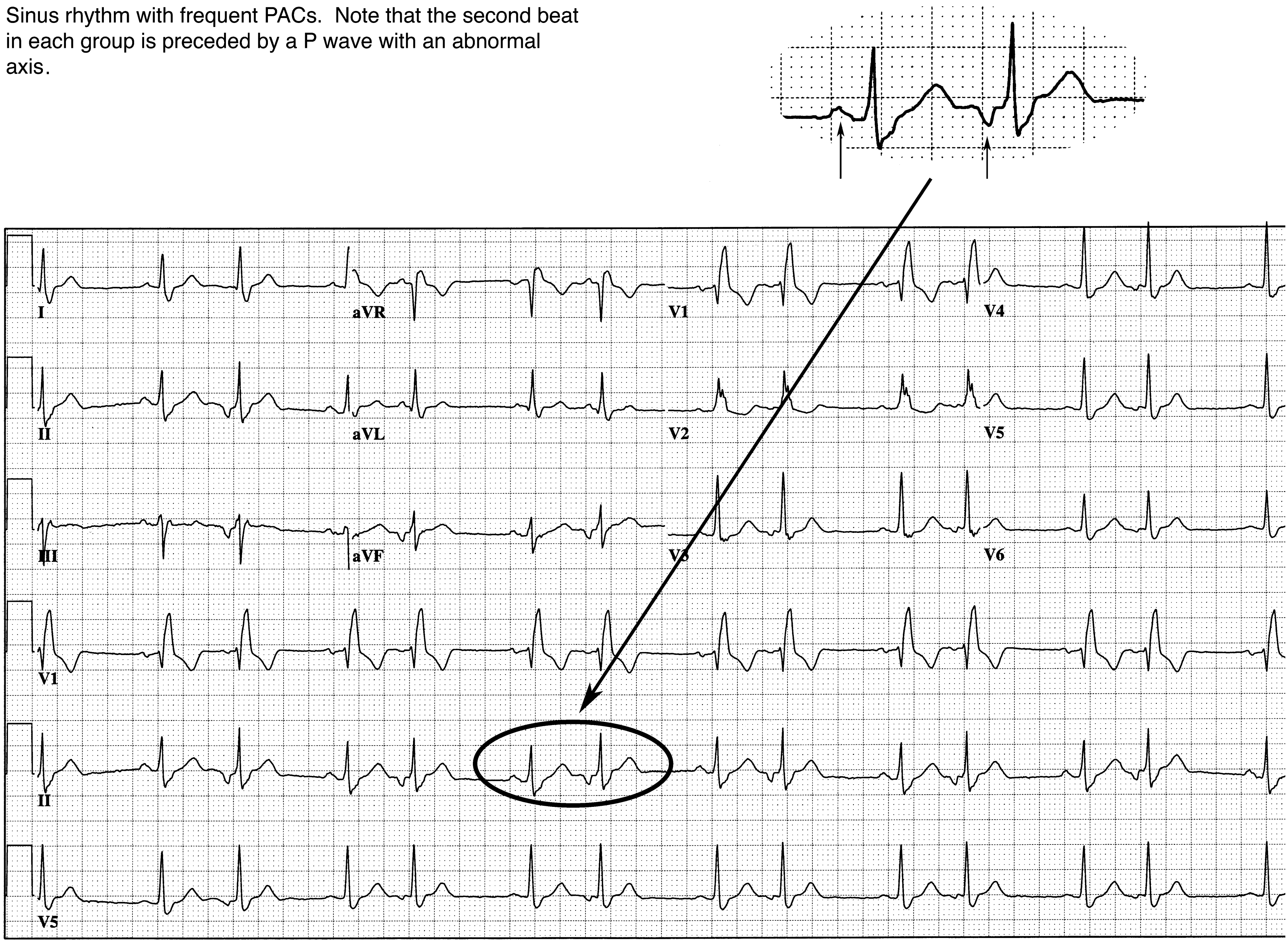
DAY 3-22

Sinus rhythm with second degree SA block type I. Note the group beating of the QRS complexes, identical P waves, and similar PR intervals.



DAY 3-23

Sinus rhythm with frequent PACs. Note that the second beat in each group is preceded by a P wave with an abnormal axis.



Sample Tracings
ECG 1

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

ST segment: ____________________

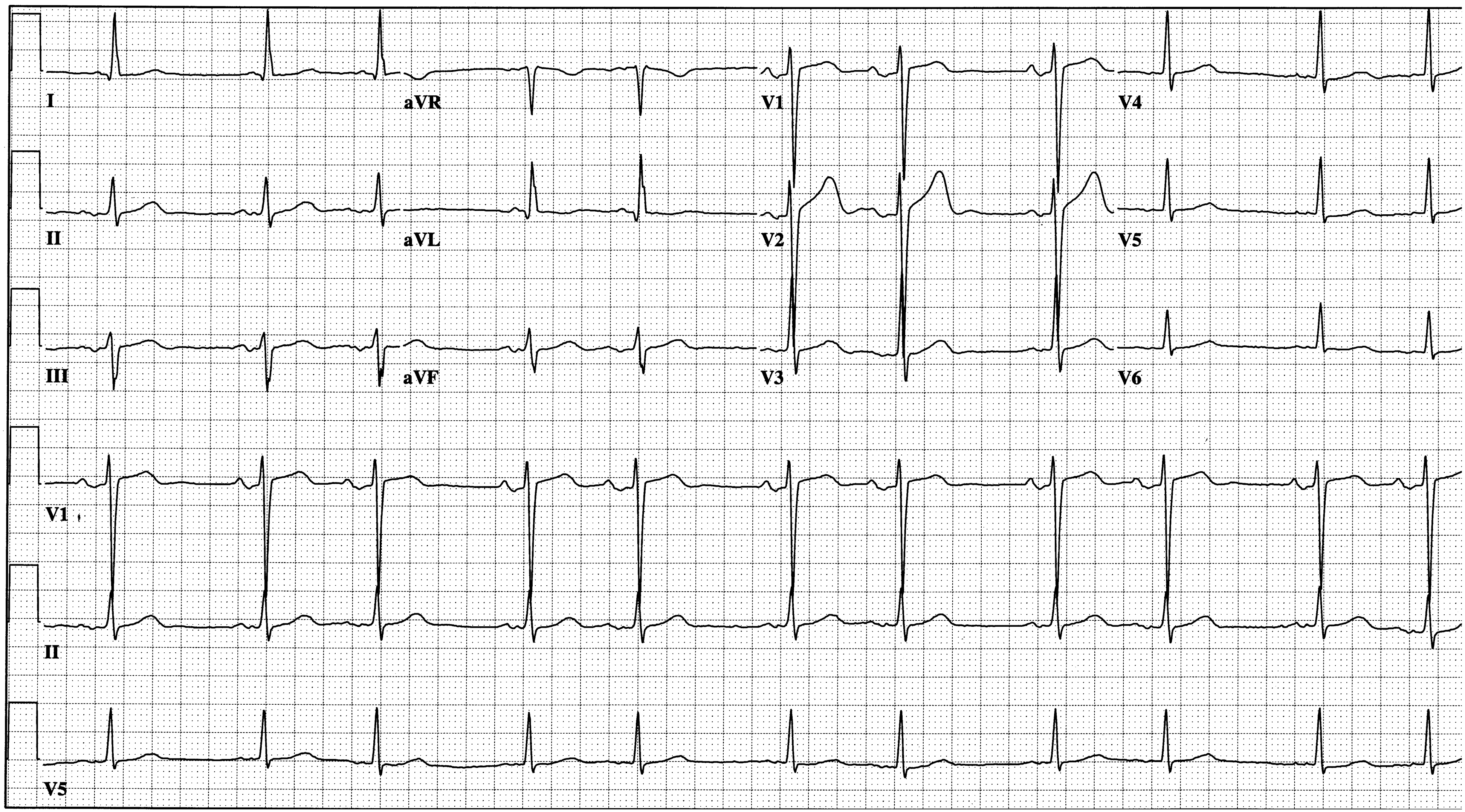
T wave: ____________________

QT interval: ____________________

U wave: ____________________

Diagnosis: ____________________

____



ECG 2

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

ST segment: ______

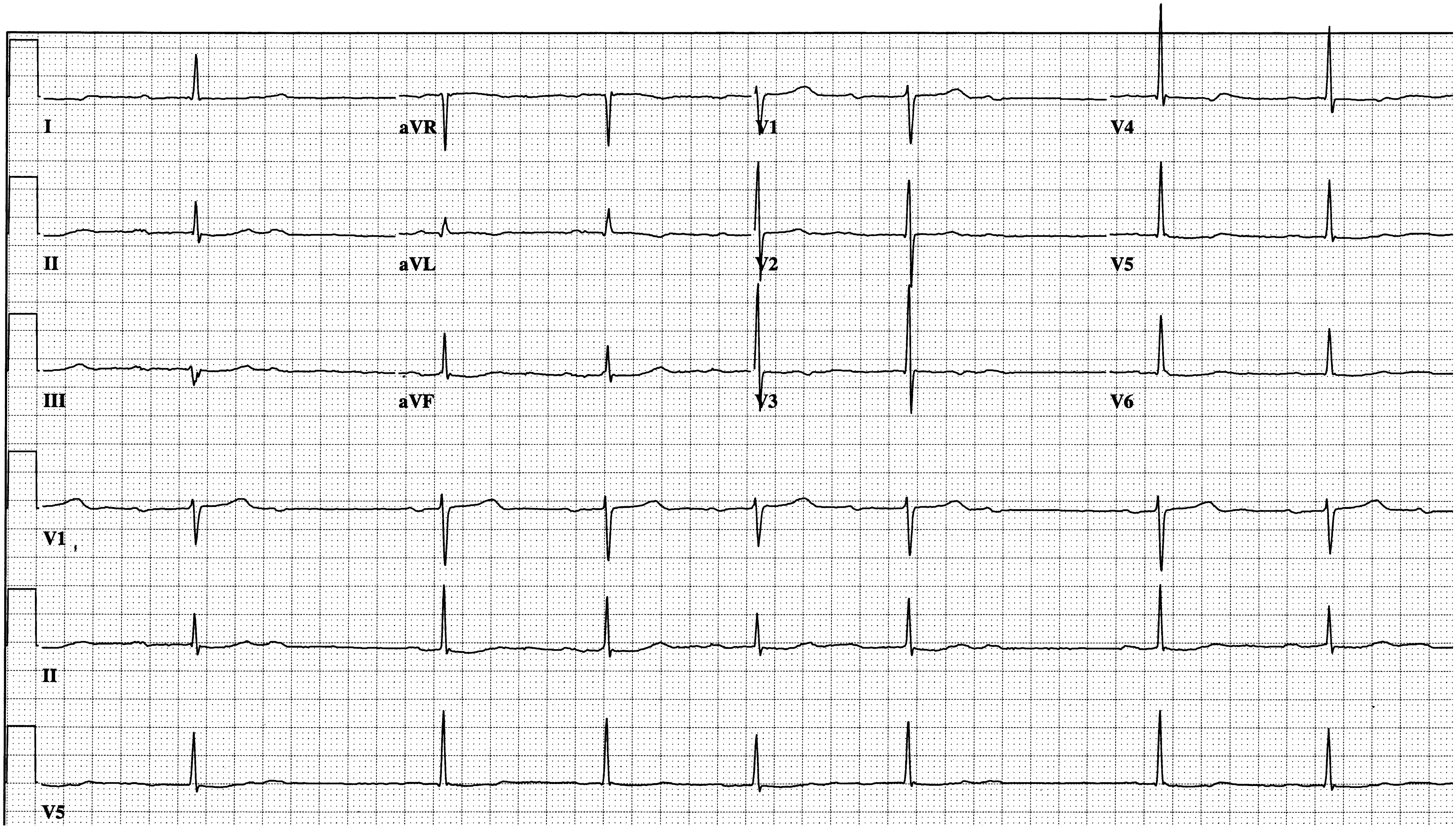
T wave: ______

QT interval: ______

U wave: ______

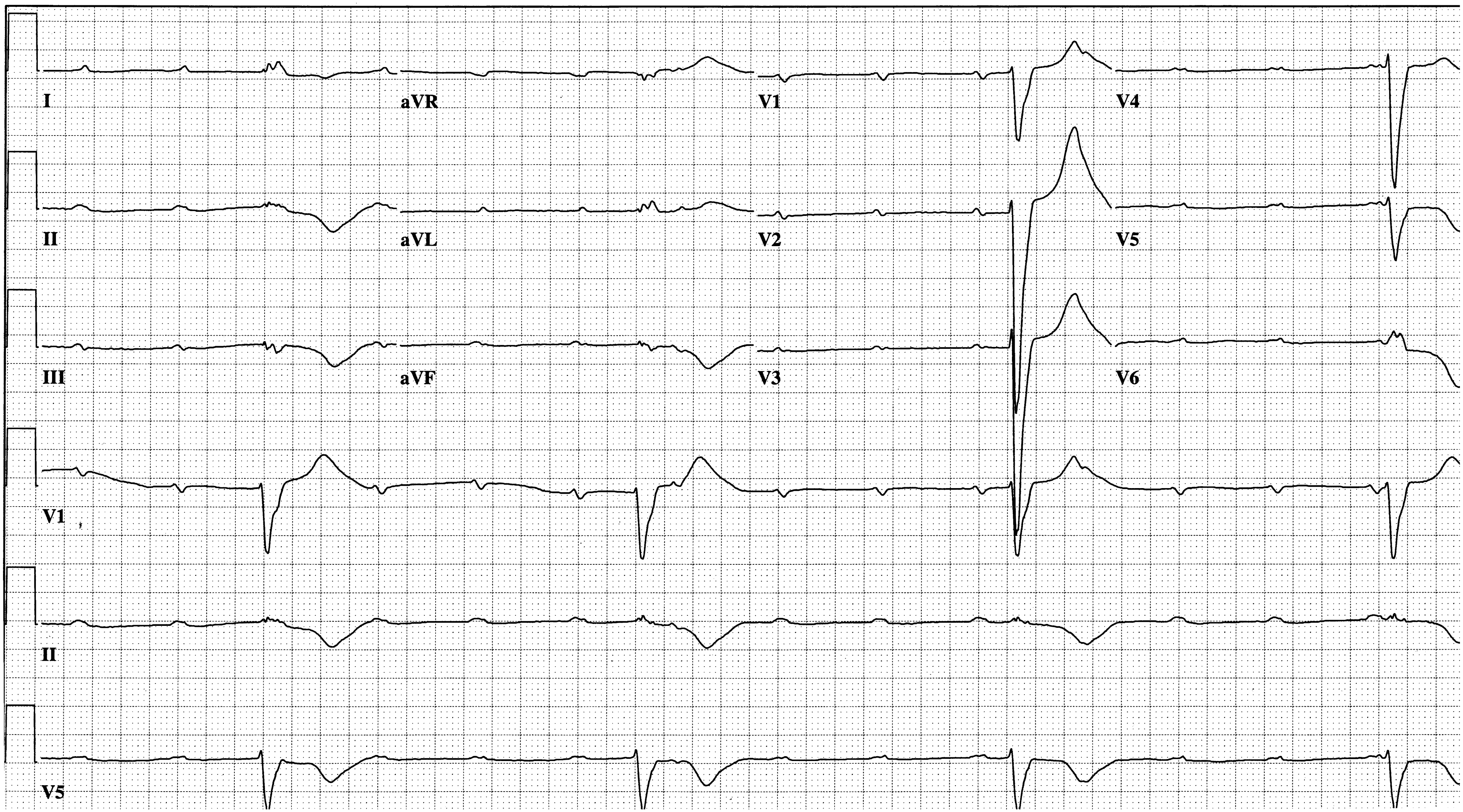
Diagnosis: ______

______



ECG 3

Atrial rate:	QRS complex:	ST segment:
Ventricular rate:	Axis:	T wave:
Rhythm:	Duration:	QT interval:
P wave:	Voltage:	U wave:
PR interval:	Morphology:	Diagnosis:



ECG 4

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

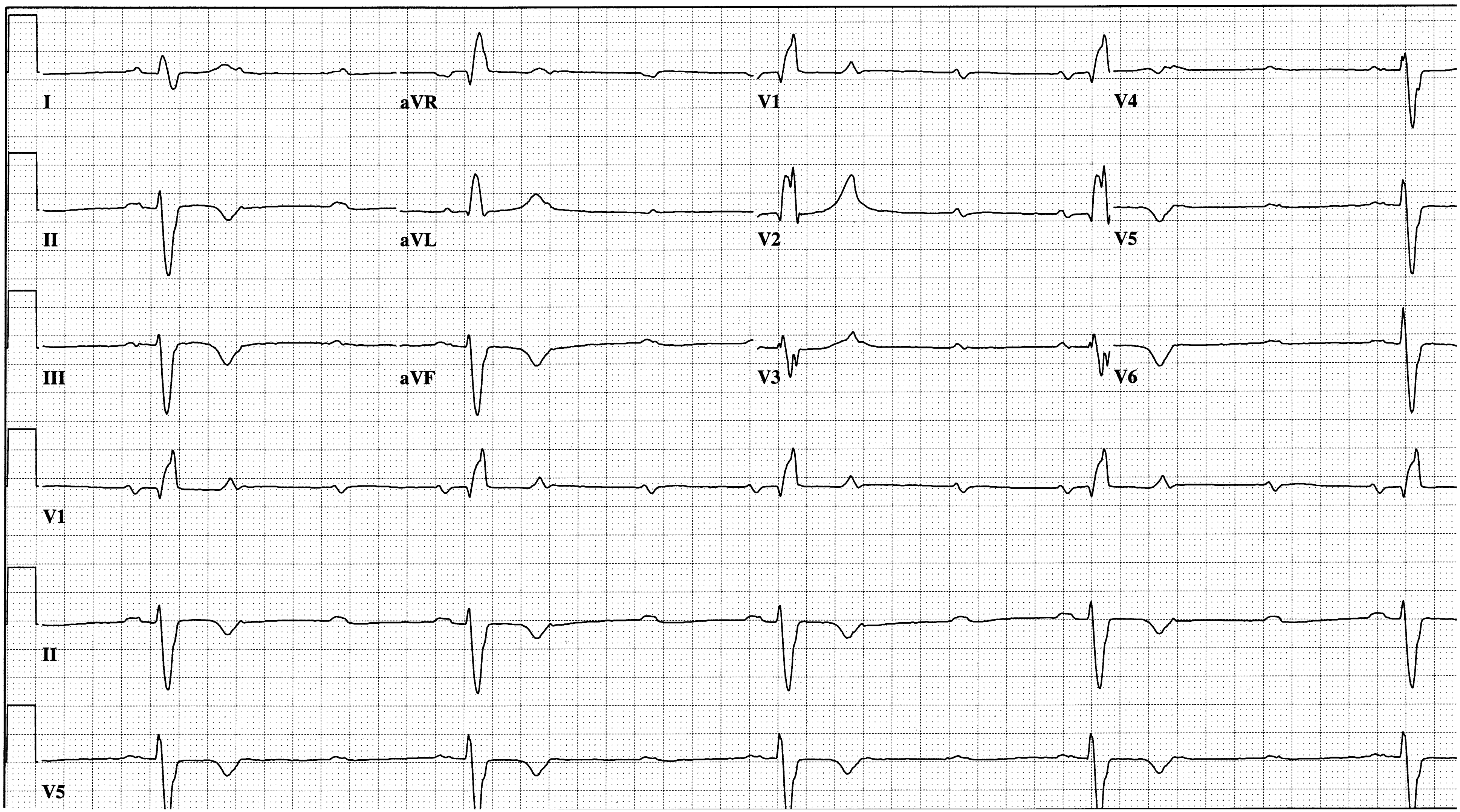
ST segment: ______

T wave: ______

QT interval: ______

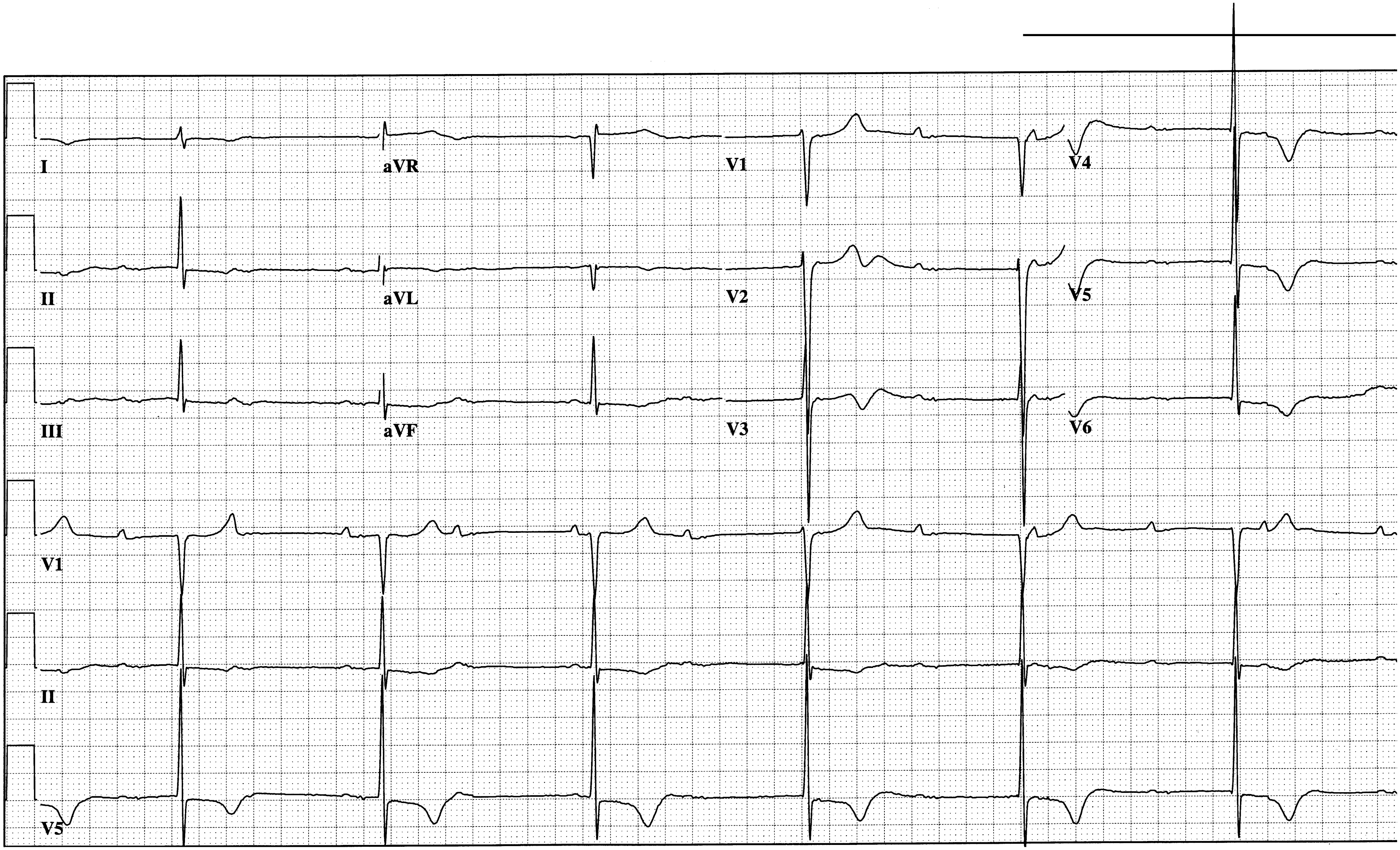
U wave: ______

Diagnosis: ______



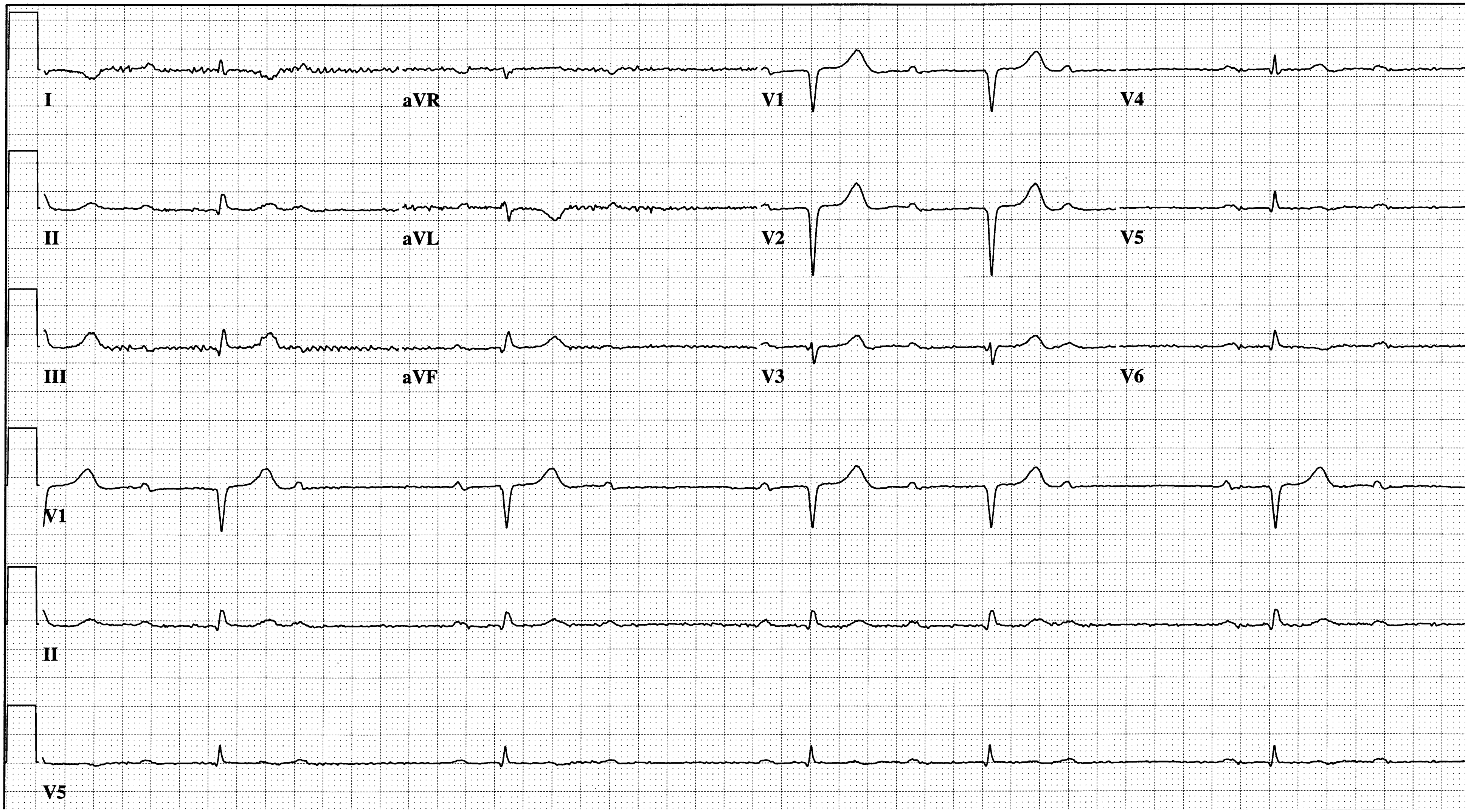
ECG 5

Atrial rate: ________	QRS complex:	ST segment: ________
Ventricular rate: ________	Axis: ________	T wave: ________
Rhythm: ________	Duration: ________	QT interval: ________
P wave: ________	Voltage: ________	U wave: ________
PR interval: ________	Morphology: ________	Diagnosis: ________



ECG 6

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG 7

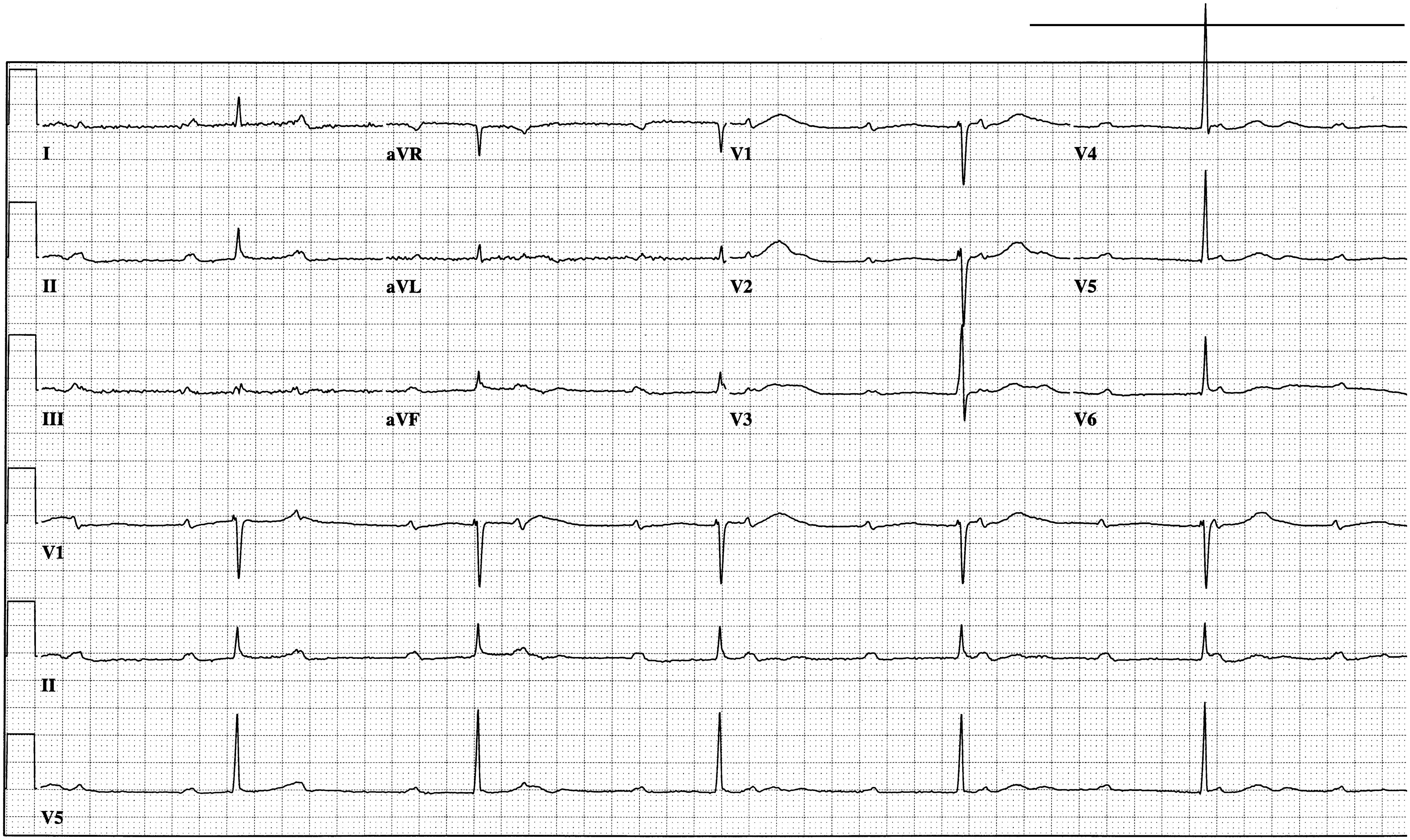
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG 8

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

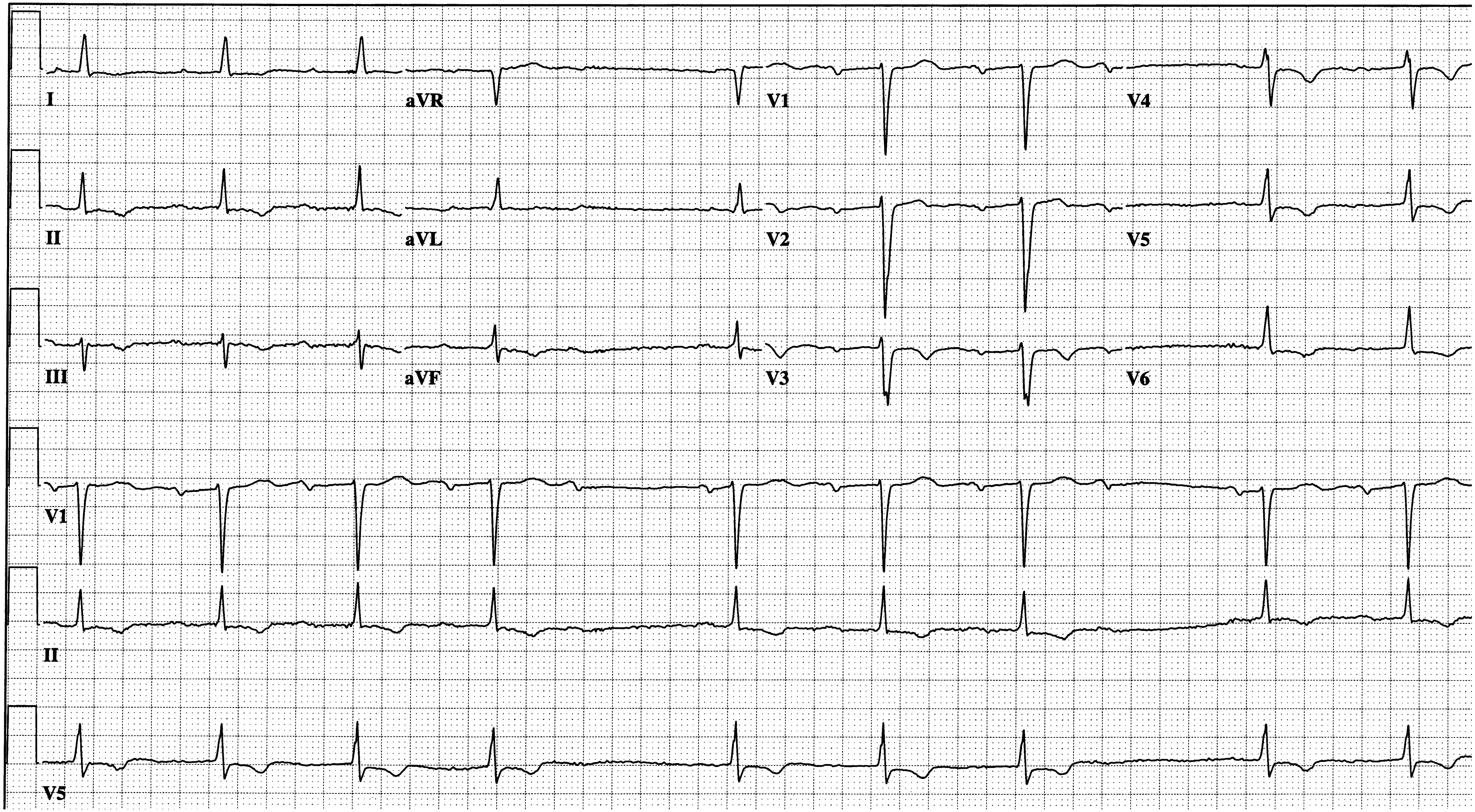
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG 9

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

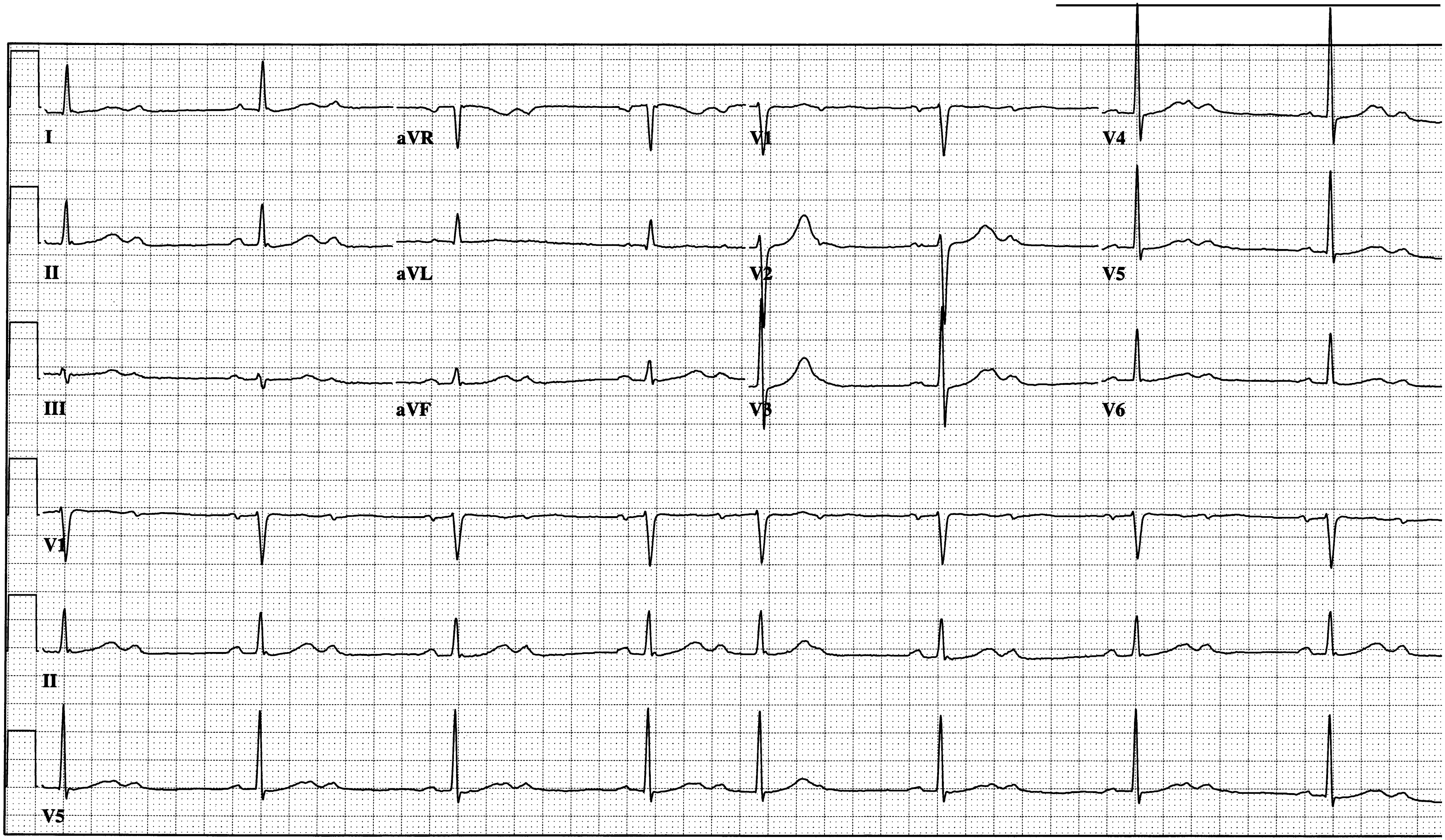
ST segment: ______________________

T wave: ______________________

QT interval: ______________________

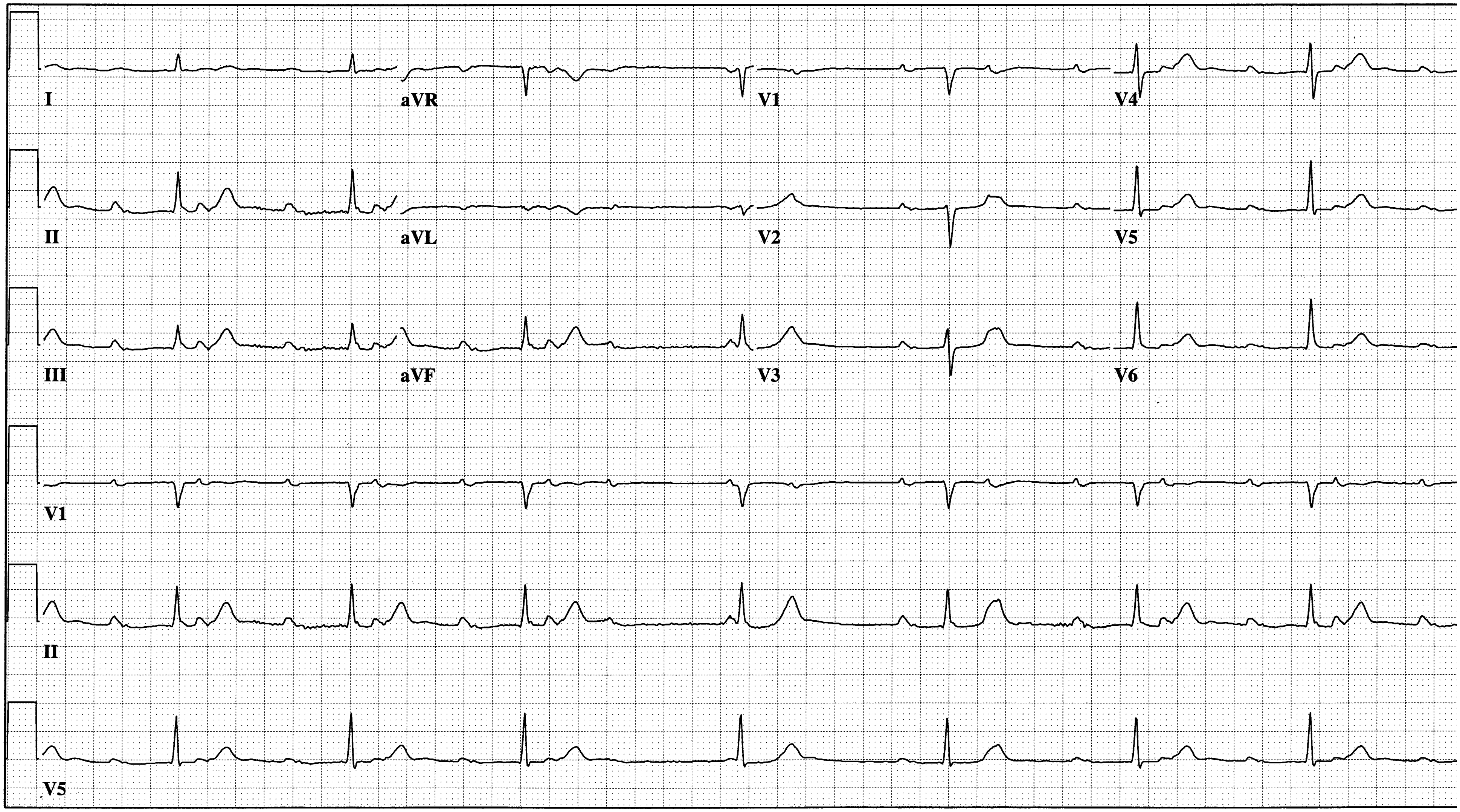
U wave: ______________________

Diagnosis: ______________________



ECG 10

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG 11

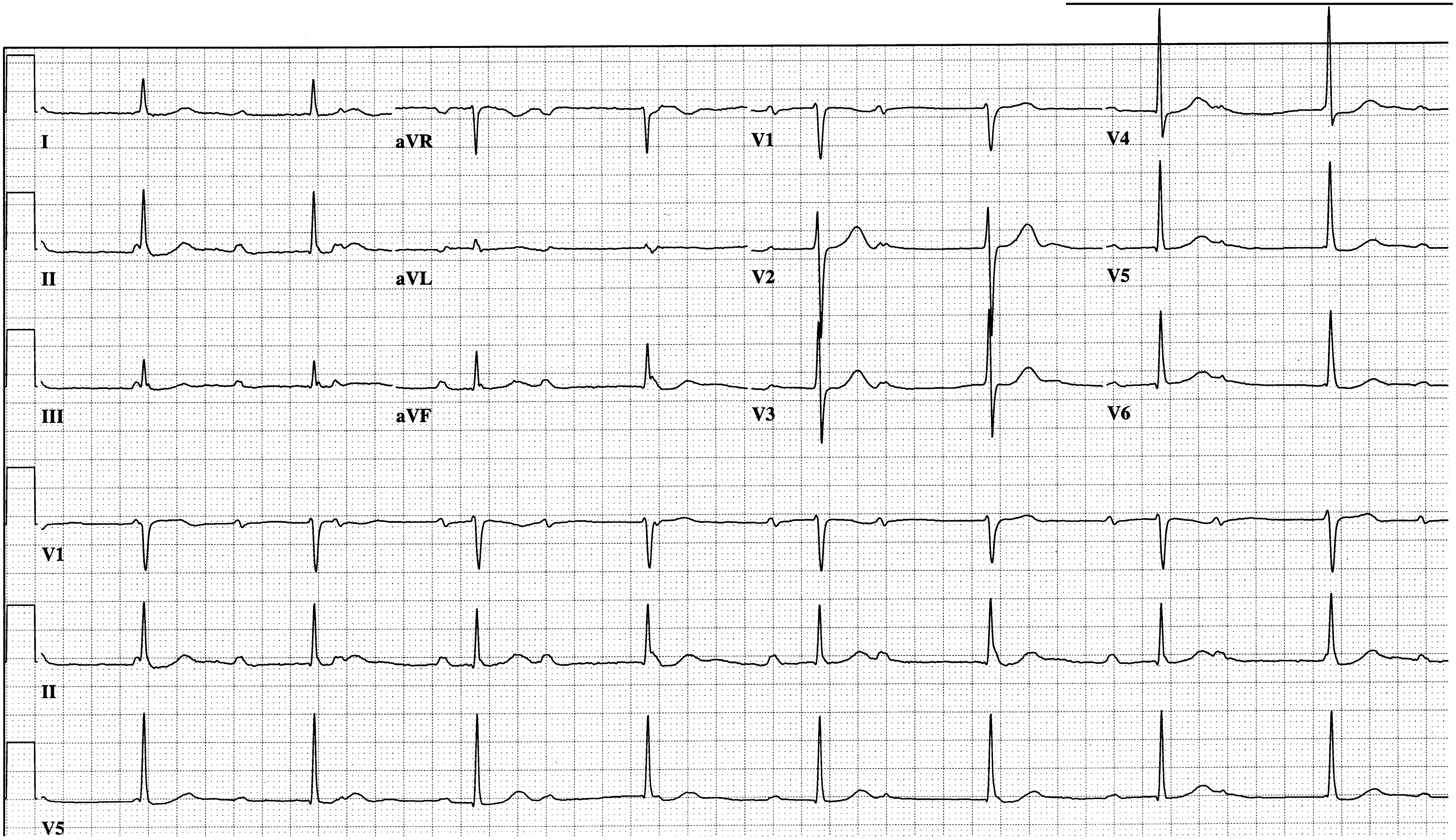
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG 12

Atrial rate: ______________

Ventricular rate: ______________

Rhythm: ______________

P wave: ______________

PR interval: ______________

QRS complex:

Axis: ______________

Duration: ______________

Voltage: ______________

Morphology: ______________

ST segment: ______________

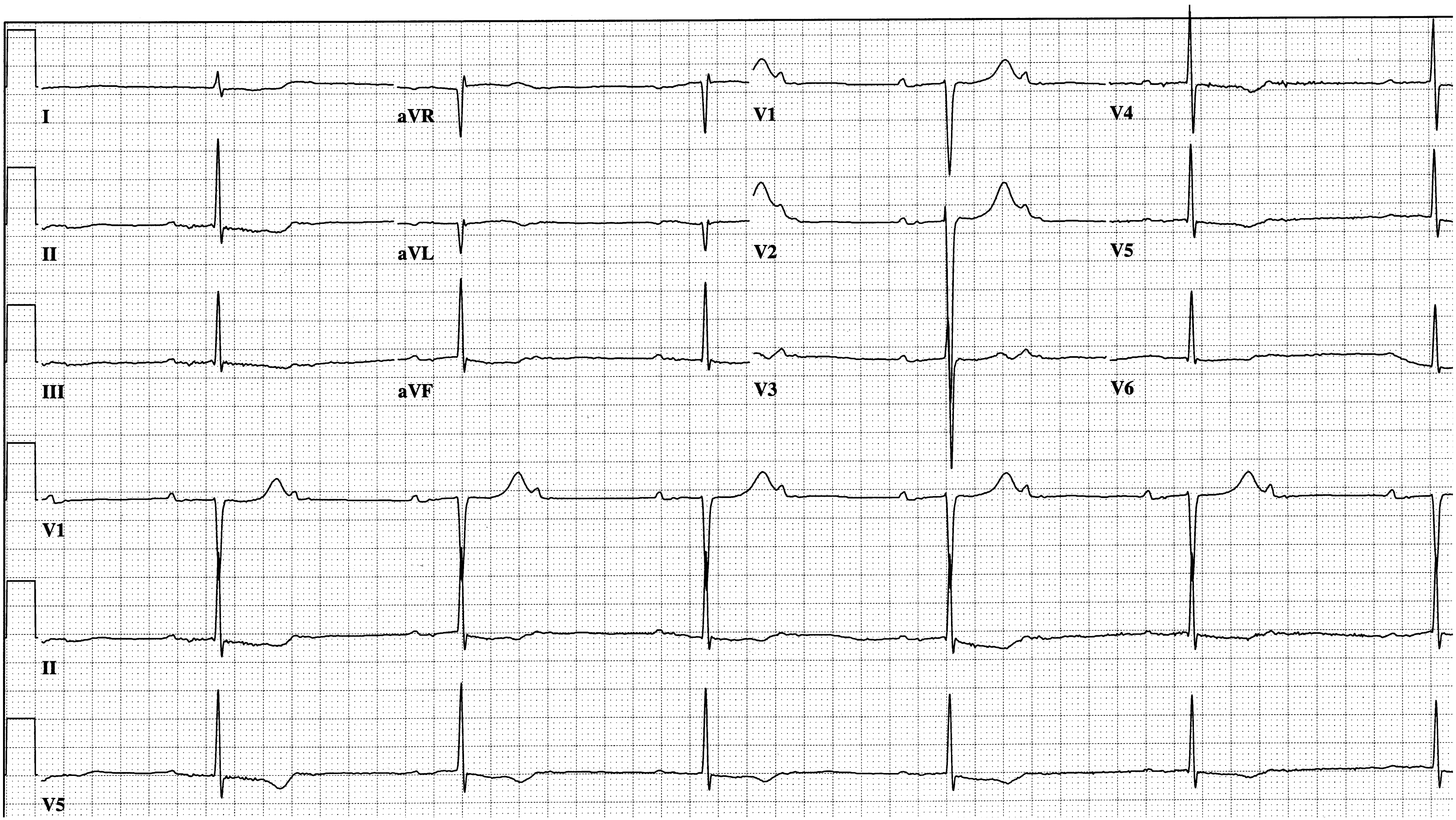
T wave: ______________

QT interval: ______________

U wave: ______________

Diagnosis: ______________

____



ECG 13

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

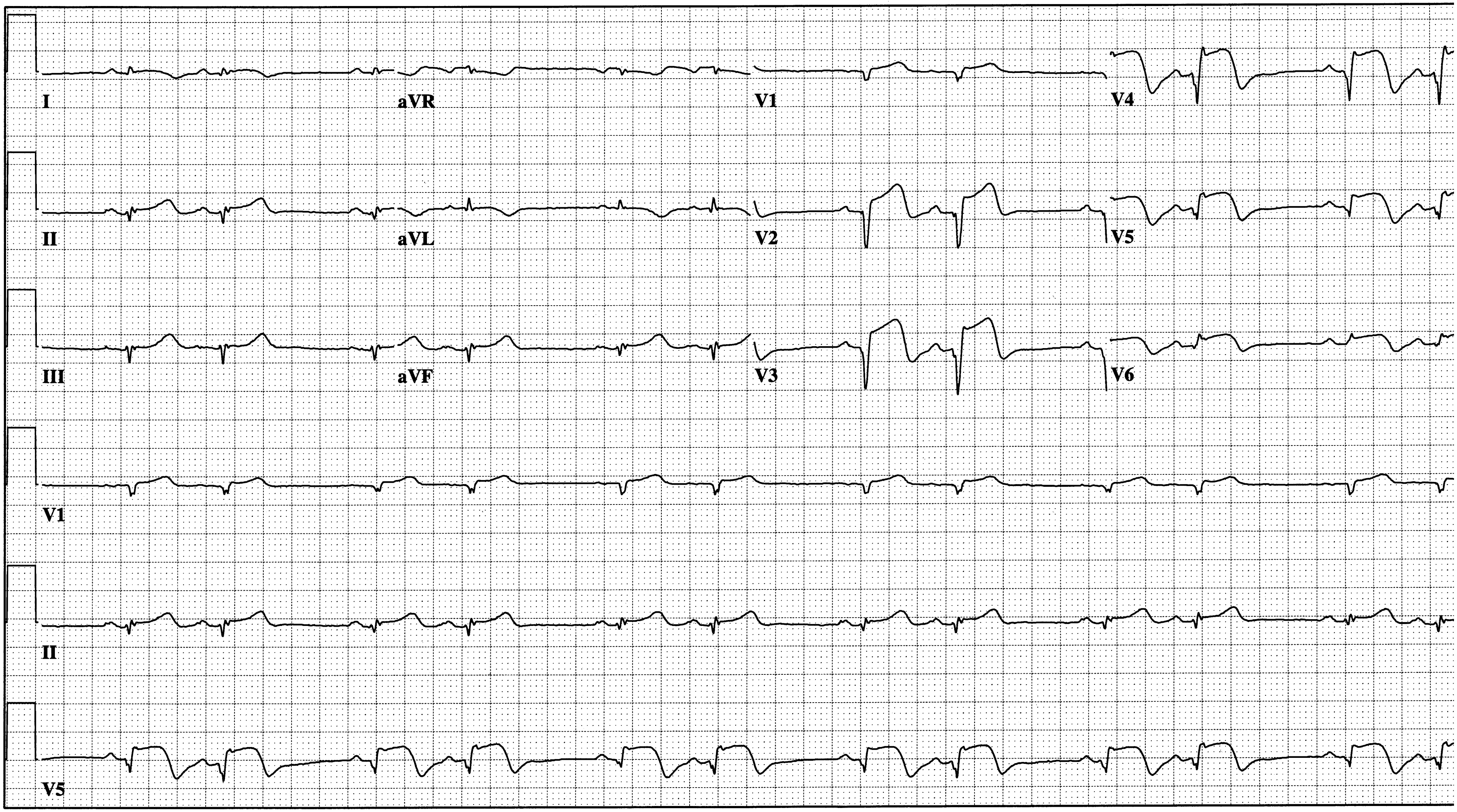
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG 14

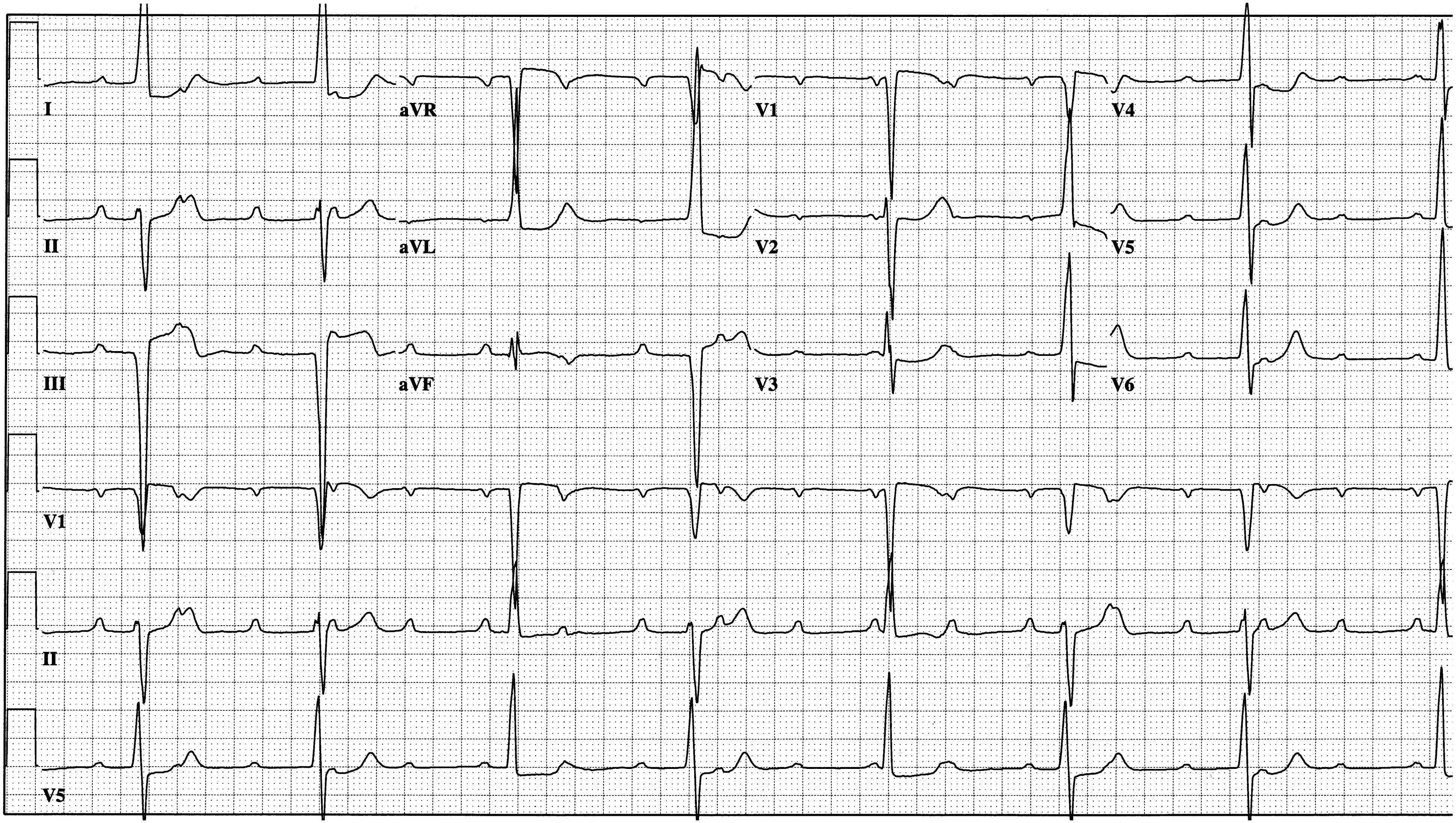
Atrial rate: ____________ QRS complex: ST segment: ____________

Ventricular rate: ____________ Axis: ____________ T wave: ____________

Rhythm: ____________ Duration: ____________ QT interval: ____________

P wave: ____________ Voltage: ____________ U wave: ____________

PR interval: ____________ Morphology: ____________ Diagnosis: ____________



ECG 15

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

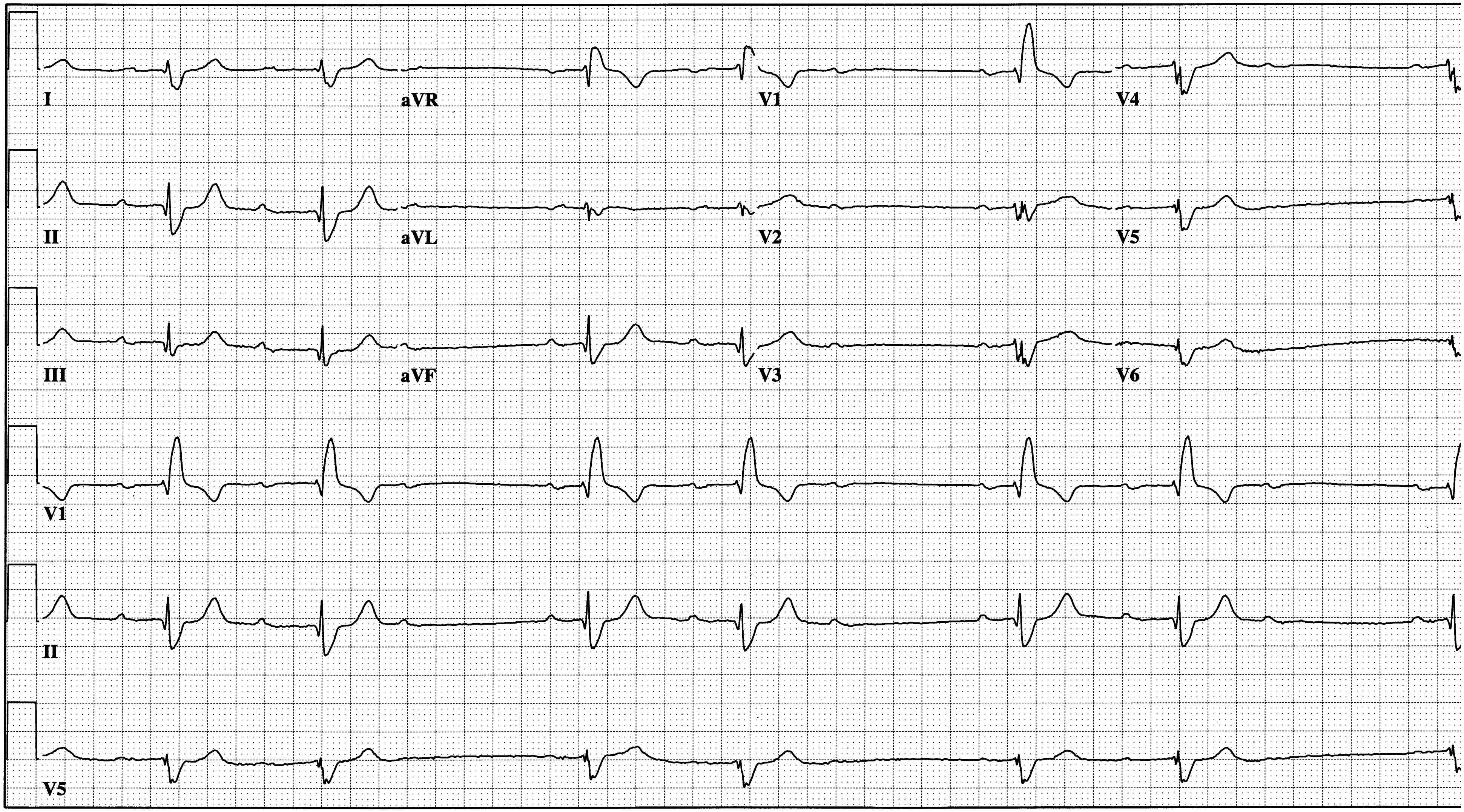
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG 16

Atrial rate: ______________

Ventricular rate: ______________

Rhythm: ______________

P wave: ______________

PR interval: ______________

QRS complex:

Axis: ______________

Duration: ______________

Voltage: ______________

Morphology: ______________

ST segment: ______________

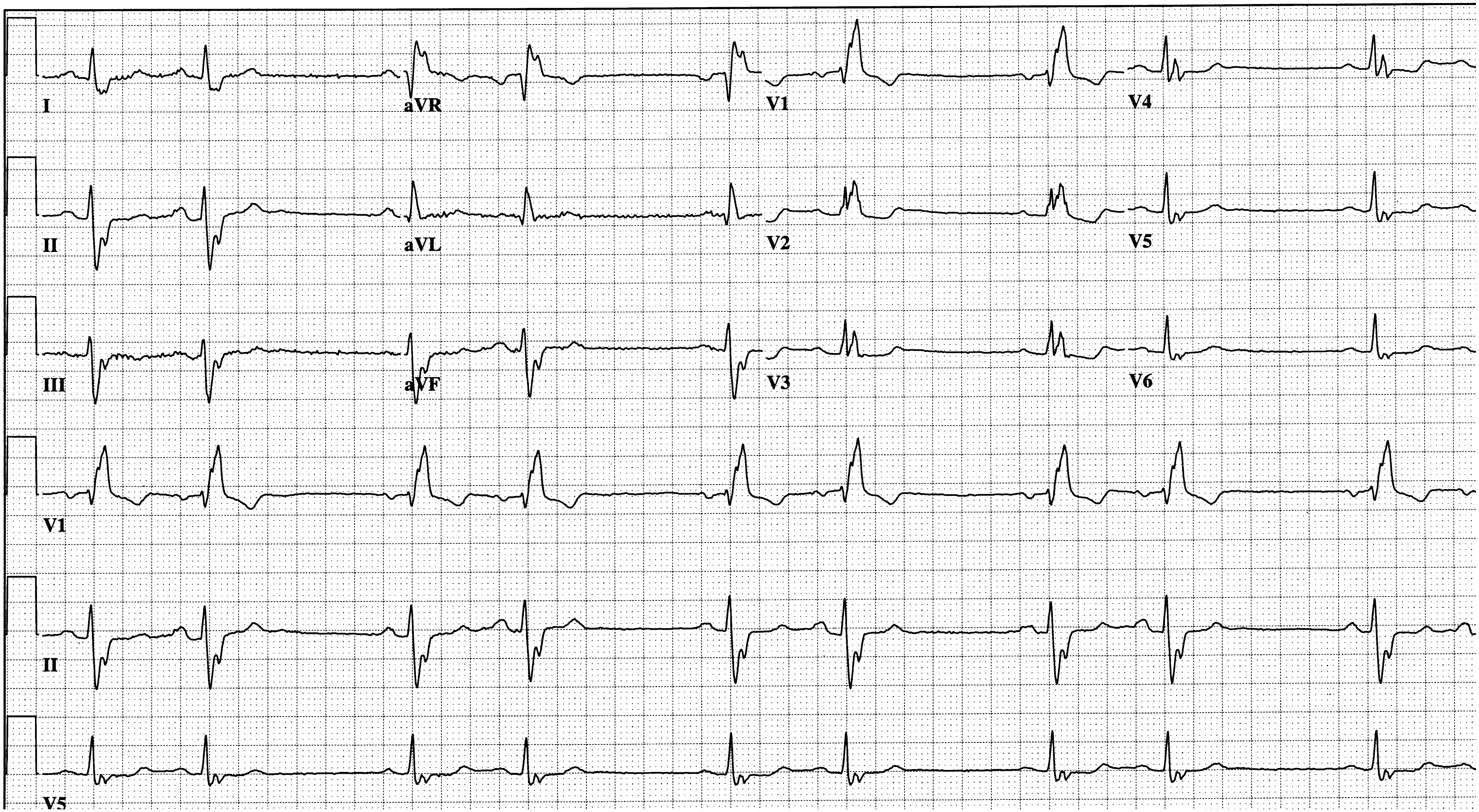
T wave: ______________

QT interval: ______________

U wave: ______________

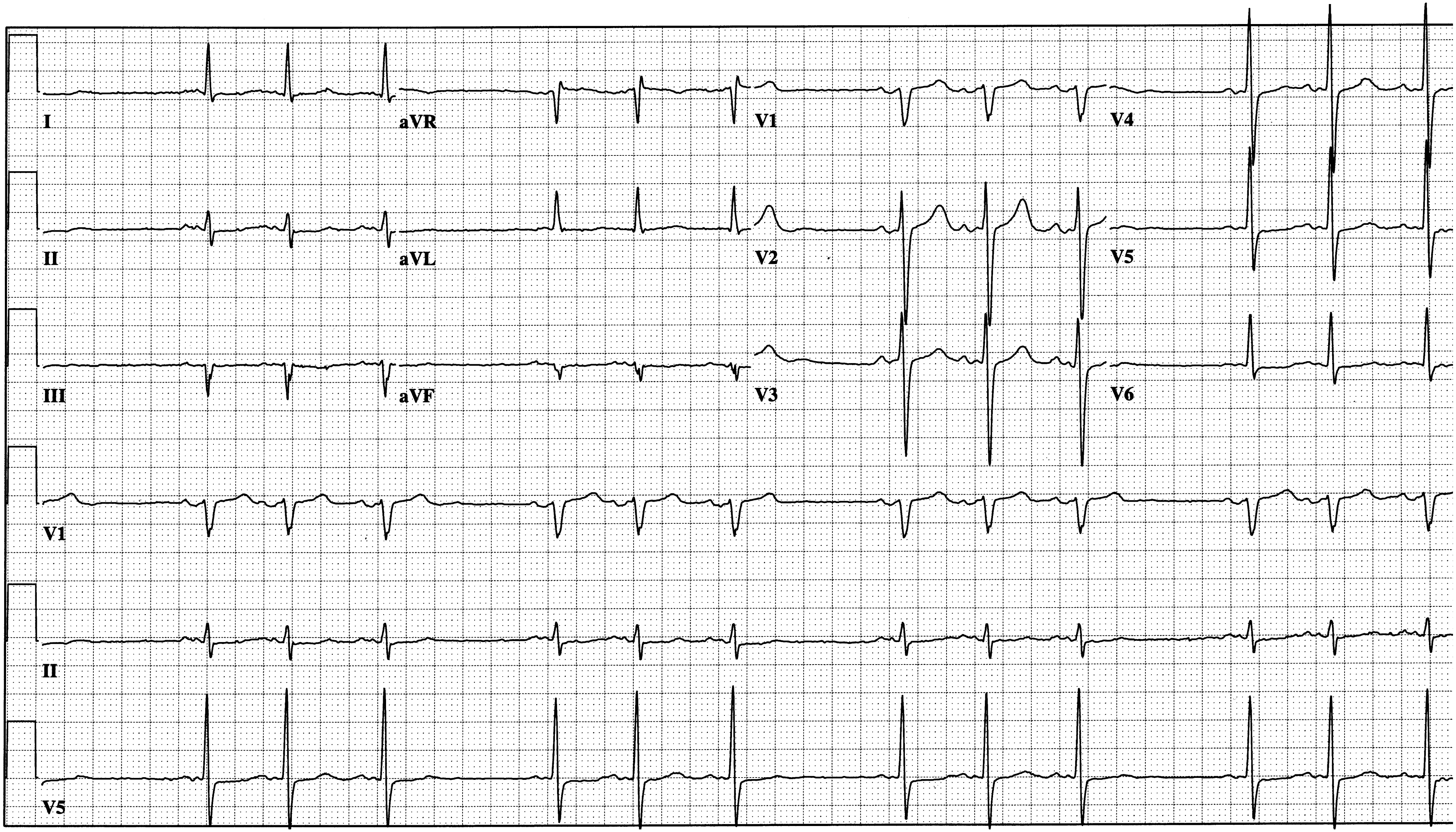
Diagnosis: ______________

____



ECG 17

Atrial rate:	QRS complex:	ST segment:
Ventricular rate:	Axis:	T wave:
Rhythm:	Duration:	QT interval:
P wave:	Voltage:	U wave:
PR interval:	Morphology:	Diagnosis:



ECG 18

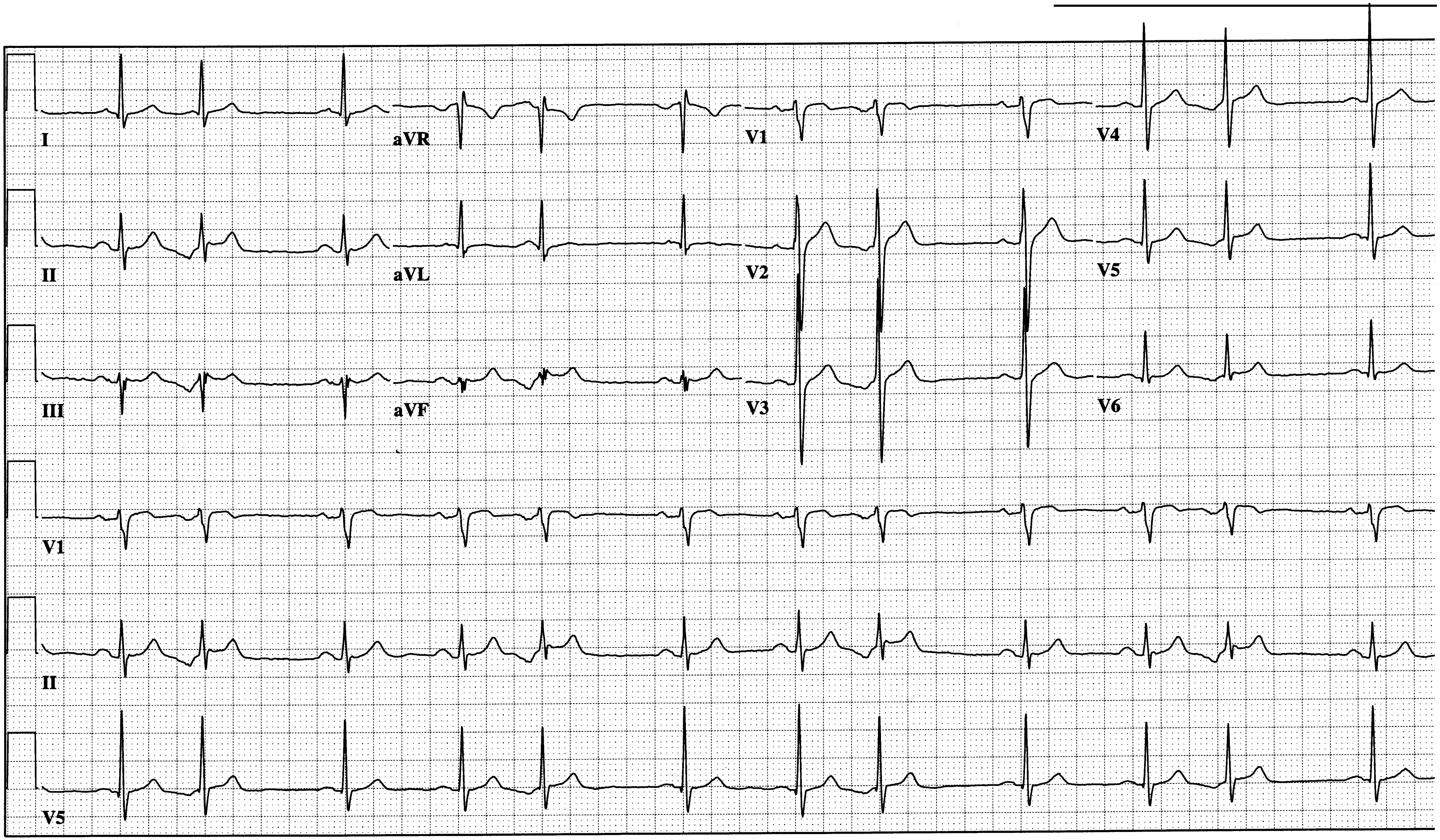
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG 19

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

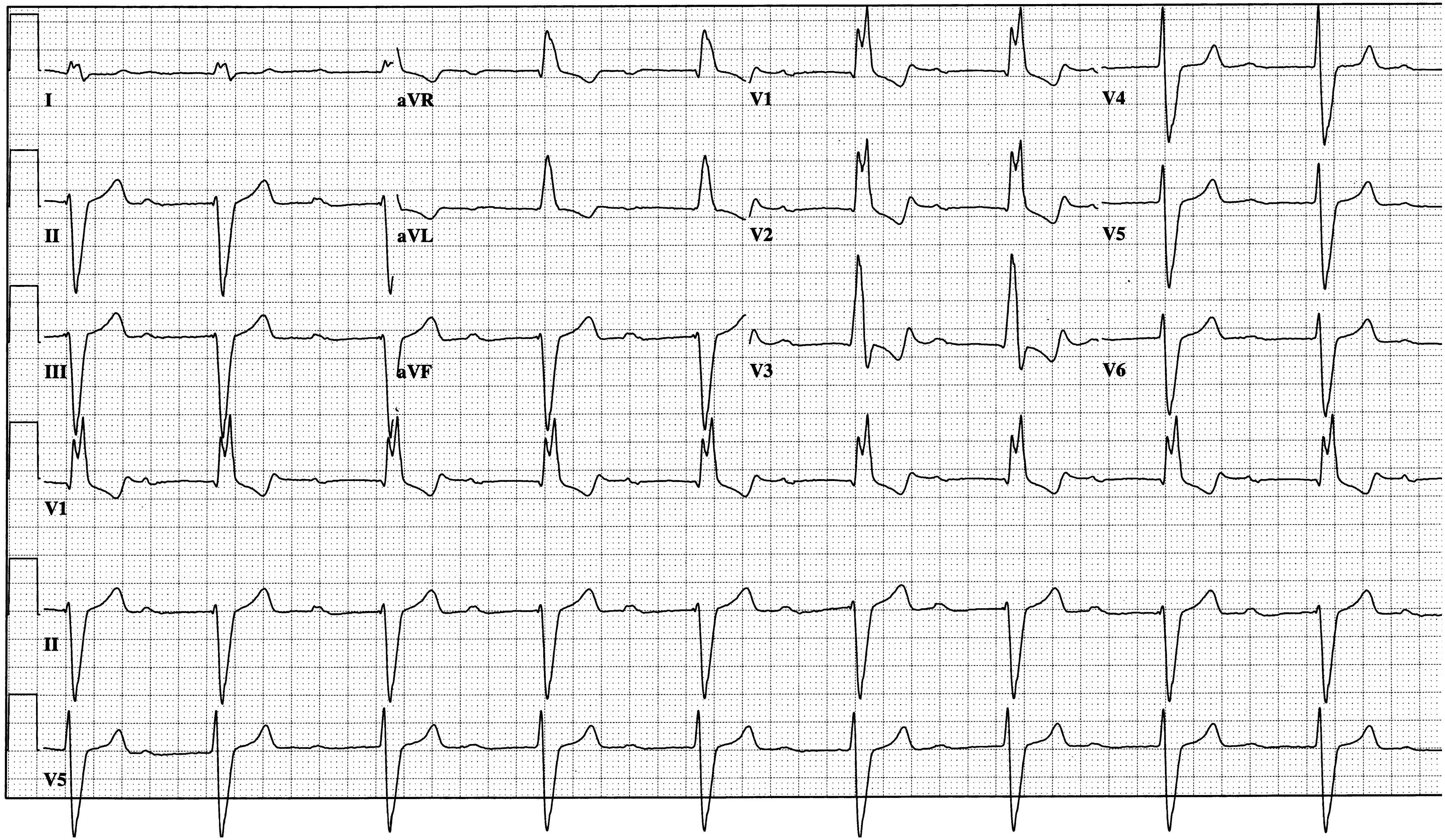
ST segment: ____________________

T wave: ____________________

QT interval: ____________________

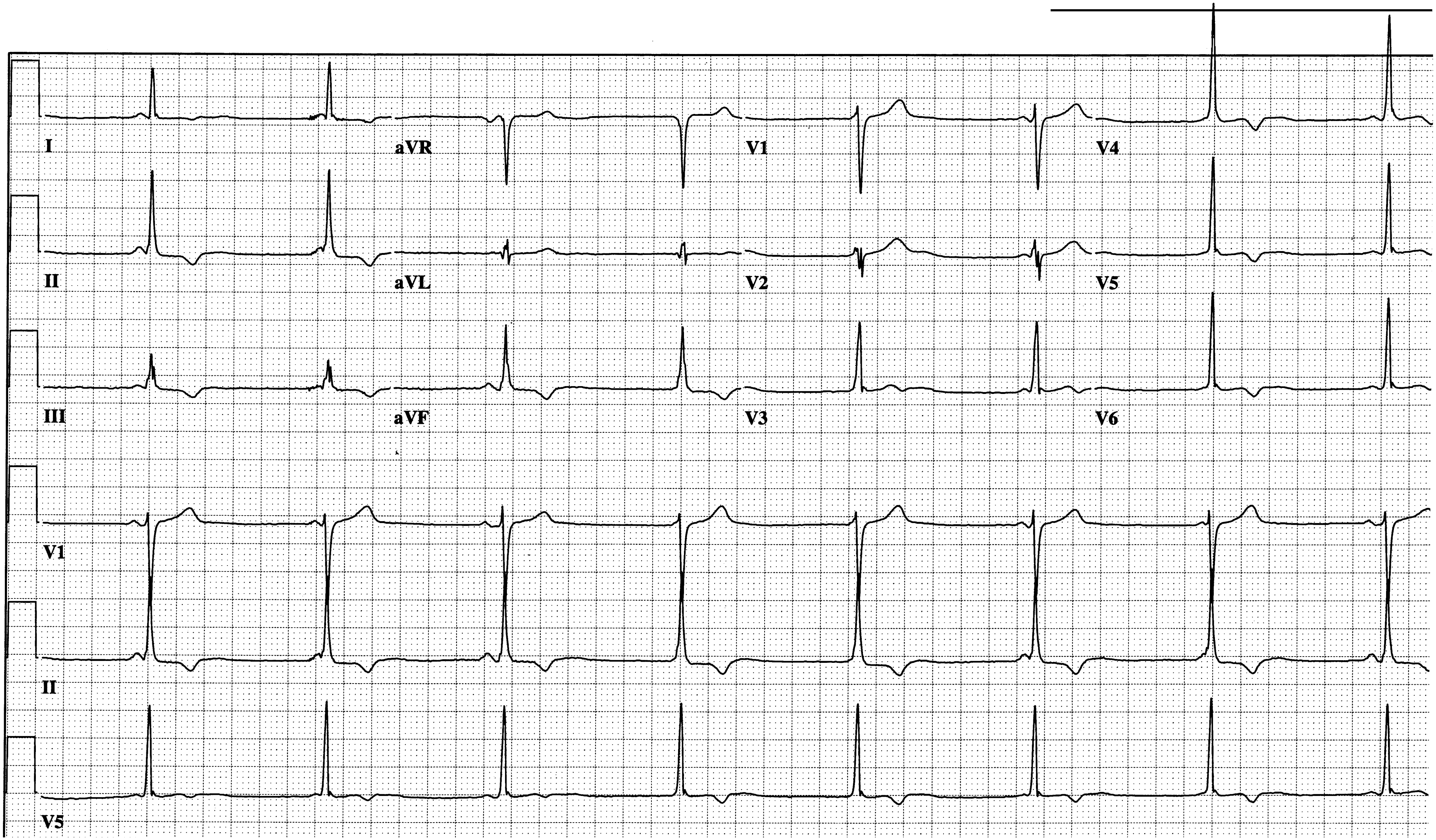
U wave: ____________________

Diagnosis: ____________________



ECG 20

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



SA and AV Nodal Conduction Abnormalities

Interpretations of Sample Tracings

ECG 1

Atrial rate: 65
Ventricular rate: 65
Rhythm: Sinus rhythm with second degree SA block type I
P wave: Normal
PR interval: 200 msec
QRS complex:
  Axis: 0°
  Duration: 95 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 420 msec
U wave:
Diagnosis: Sinus rhythm with second degree SA block type I (note the identical P waves and the unchanging PR intervals)

ECG 2

Atrial rate: 60
Ventricular rate: 45
Rhythm: Sinus rhythm with second degree AV block type I
P wave: Normal
PR interval:
QRS complex:
  Axis: 30°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Nonspecific changes
QT interval: 450 msec
U wave:
Diagnosis: Sinus rhythm with second degree AV block type I

ECG 3

Atrial rate: 85
Ventricular rate: 22
Rhythm: Sinus rhythm with complete heart block and a slow ventricular escape rhythm
P wave: Normal

PR interval:
QRS complex:
Axis: 0°
Duration: 160 msec
Voltage:
Morphology:
ST segment:
T wave:
QT interval: 780 msec
U wave:
Diagnosis: Sinus rhythm with complete heart block and a slow ventricular escape rhythm. This patient actually had severe hyperkalemia.

ECG 4

Atrial rate: 80
Ventricular rate: 27
Rhythm: Sinus rhythm with high grade AV block
P wave: Normal
PR interval:
QRS complex:
Axis: –90°
Duration: 160 msec RBBB, left anterior fascicular block (LAFB)
Voltage: Normal
Morphology: Q waves in V_1 and V_2
ST segment: Normal
T wave: Diffuse t wave inversion
QT interval: 750 msec
U wave:
Diagnosis: Sinus rhythm with high grade AV block, probably second degree AV block type II, RBBB, left anterior fascicular block (left axis deviation ≥45°, tiny Q wave in aVL and an IVCD), and a previous septal MI (the expected R wave of the RSR' in V_1 has been replaced by a Q wave)

ECG 5

Atrial rate: 75
Ventricular rate: 38
Rhythm: Sinus rhythm with complete heart block
P wave: Normal
PR interval:
QRS complex:
Axis: 90°
Duration: 80 msec
Voltage: Increased in V_2 to V_5
Morphology: Normal

ST segment: Nonspecific changes
T wave: Widespread T wave inversions
QT interval: 550 msec
U wave: Prominent U waves in V_2 and V_3
Diagnosis: Sinus rhythm with complete heart block and a junctional escape rhythm, and voltage criteria for LVH

ECG 6

Atrial rate: 58
Ventricular rate: 32
Rhythm: Sinus rhythm with second degree AV block type I
P wave: Normal
PR interval:
QRS complex:
  Axis: 70°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Q waves in V_1 to V_3
ST segment: Normal
T wave: Inverted in I and aVL
QT interval: 660 msec
U wave:
Diagnosis: Sinus rhythm with second degree AV block type I and an old anteroseptal MI

ECG 7

Atrial rate: 75
Ventricular rate: 34
Rhythm: Sinus rhythm with complete heart block and a junctional escape rhythm
P wave: Normal
PR interval:
QRS complex:
  Axis: 45°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Nonspecific changes
QT interval: 600 msec
U wave: Prominent U waves in V_2 to V_5
Diagnosis: Sinus rhythm with complete heart block and a junctional escape rhythm

ECG 8

Atrial rate: 70
Ventricular rate: 52
Rhythm: Sinus rhythm with second degree AV block type I
P wave: Normal
PR interval:
QRS complex:
  Axis: 20°
  Duration: 110 msec
  Voltage: Normal
  Morphology:
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 440 msec
U wave:
Diagnosis: Sinus rhythm with second degree AV block type I and nonspecific ST-T wave changes. The delayed precordial transition suggests, but does not prove, a previous anteroseptal MI.

ECG 9

Atrial rate: 85
Ventricular rate: 46
Rhythm: Sinus rhythm with second degree AV block type I
P wave: Normal
PR interval:
QRS complex:
  Axis: 20°
  Duration: 90 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 460 msec
U wave:
Diagnosis: Sinus rhythm with second degree AV block type I

ECG 10

Atrial rate: 95
Ventricular rate: 45
Rhythm: Sinus rhythm with occasional premature atrial complexes (PACs) and high grade AV block
P wave: Normal

PR interval:
QRS complex:
  Axis: 60°
  Duration: 80 msec
  Voltage: Low voltage
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 460 msec
U wave:
Diagnosis: Sinus rhythm with occasional PACs and high grade AV block with primarily a junctional escape rhythm. Since the ventricular rhythm is not regular, there is not complete heart block.

ECG 11

Atrial rate: 85
Ventricular rate: 50
Rhythm: Sinus rhythm with complete heart block and a junctional escape rhythm
P wave: Normal
PR interval:
QRS complex:
  Axis: 60°
  Duration: 90 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 460 msec
U wave:
Diagnosis: Sinus rhythm with complete heart block and a junctional escape rhythm.

ECG 12

Atrial rate: 70
Ventricular rate: 35
Rhythm: Sinus rhythm with second degree AV block, probably type I
P wave: Normal
PR interval:
QRS complex:
  Axis: 75°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Nonspecific changes
T wave: Nonspecific changes

QT interval: 620 msec
U wave:
Diagnosis: Sinus rhythm with second degree AV block and nonspecific ST-T wave changes. Since the groups consist of two P waves and one QRS complex, it is impossible to be certain whether this is type I or type II second degree AV block, although the narrow QRS complexes strongly suggest type I.

ECG 13

Atrial rate: 71
Ventricular rate: 71
Rhythm: Sinus rhythm with second degree SA type I
P wave: Normal
PR interval: 170 msec
QRS complex:
  Axis: −45°
  Duration: 90 msec
  Voltage: Low voltage
  Morphology: Q waves in II, III, and aVF, and V_1 to V_5
ST segment: Hyperacute ST segment elevation in V_1 to V_6 and somewhat in I
T wave: Inverted in I, aVL, and V_2 to V_6
QT interval: 320 msec
U wave:
Diagnosis: Sinus rhythm with second degree SA block type I, left axis deviation, low voltage, acute anterior and lateral MI, and probable old inferior MI

ECG 14

Atrial rate: 115
Ventricular rate: 46
Rhythm: Sinus tachycardia with complete heart block and a junctional escape rhythm
P wave: Normal
PR interval:
QRS complex:
  Axis: 0°
  Duration: 100 msec
  Voltage: Increased in I and aVL
  Morphology: Possible inferior MI
ST segment: Elevated in II, III, and aVF and depressed in several other leads
T wave: Normal
QT interval: 520 msec
U wave: Normal
Diagnosis: Sinus tachycardia with complete heart block, a junctional escape rhythm, LVH by voltage criteria in I and aVL, possible old inferior MI, and ST segment elevation suggesting acute inferior injury. There is also a curious change in QRS morphology in beats 3 and 5, possibly representing electrical alternans.

ECG 15

Atrial rate: 60
Ventricular rate: 40
Rhythm: Sinus rhythm with second degree AV block type I
P wave: Normal
PR interval:
QRS complex:
  Axis: 180°
  Duration: 160 msec, RBBB
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Nonspecific changes
QT interval: 480 msec
U wave:
Diagnosis: Sinus rhythm with second degree AV block type I and RBBB

ECG 16

Atrial rate: 54
Ventricular rate: 54
Rhythm: Sinus rhythm with second degree SA block type I
P wave: Normal
PR interval: 200 msec
QRS complex:
  Axis: –60°
  Duration: 160 msec, RBBB, LAFB
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 460 msec
U wave:
Diagnosis: Sinus rhythm with second degree SA block type I, left axis deviation, RBBB, and left anterior fascicular block (left axis deviation ≥45°, tiny Q wave in aVL, and an IVCD)

ECG 17

Atrial rate: 77
Ventricular rate: 77
Rhythm: Sinus rhythm with second degree SA block type I
P wave: Normal
PR interval: 160 msec

QRS complex:
Axis: –20°
Duration: 80 msec
Voltage: Normal
Morphology: Normal
ST segment: Normal
T wave: Nonspecific changes
QT interval: 380 msec
U wave:
Diagnosis: Sinus rhythm with second degree SA block type I and nonspecific T wave changes

ECG 18

Atrial rate: 74
Ventricular rate: 74
Rhythm: Sinus rhythm with regular PACs
P wave: Normal
PR interval: 160 msec
QRS complex:
Axis: 0°
Duration: 80 msec
Voltage: Normal
Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 360 msec
U wave:
Diagnosis: Sinus rhythm with regular PACs producing group beating of the QRS complexes

ECG 19

Atrial rate: 54
Ventricular rate: 54
Rhythm: Sinus rhythm with first degree AV block
P wave: Normal
PR interval: 1040 msec
QRS complex:
Axis: –90°
Duration: 180 msec, RBBB
Voltage: Normal
Morphology: Small Q waves in V_1 and V_2
ST segment: Normal
T wave: Inverted in aVL
QT interval: 480 msec

U wave:
Diagnosis: Sinus rhythm with an extremely long first degree AV block, left axis deviation, RBBB, and possible old septal MI, and nonspecific T wave changes

ECG 20

Atrial rate: 47
Ventricular rate: 47
Rhythm: Sinus rhythm with a competing junctional rhythm
P wave: Normal
PR interval:
QRS complex:
  Axis: 60°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Diffuse T wave inversion
QT interval: 420 msec
U wave:
Diagnosis: Sinus rhythm with a junctional rhythm occurring at virtually identical rate. Whichever rhythm is slightly faster dictates the ventricular rate. Although there is nothing wrong with AV nodal conduction, this is a rare example of AV dissociation, in this case called isorhythmic AV dissociation.

Day 4

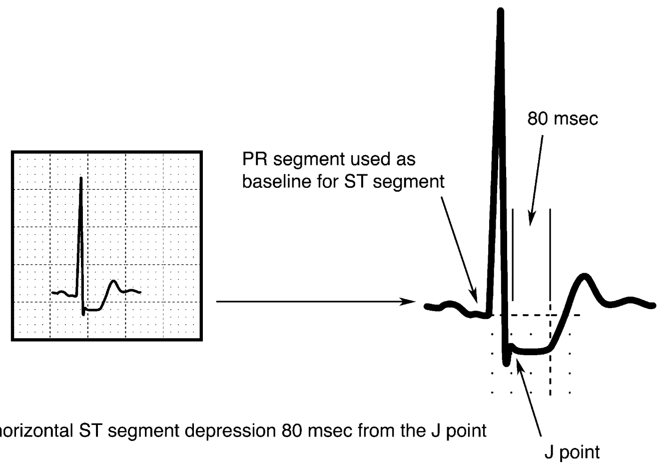
Ischemia and Infarction

I. The ST segment and T wave in ischemia

A. There are over 100 identified causes of ST segment and T wave changes, so the diagnosis of ischemia and infarction frequently requires comparison with previous ECGs and correlation with the clinical presentation and laboratory data.

B. Myocardial ischemia produces a range of changes in the ST segment and T wave, depending on the severity of ischemia and the timing of the ECG.

C. The specificity of the ST segment for ischemia is dependent on its morphology. (Day 4-01)

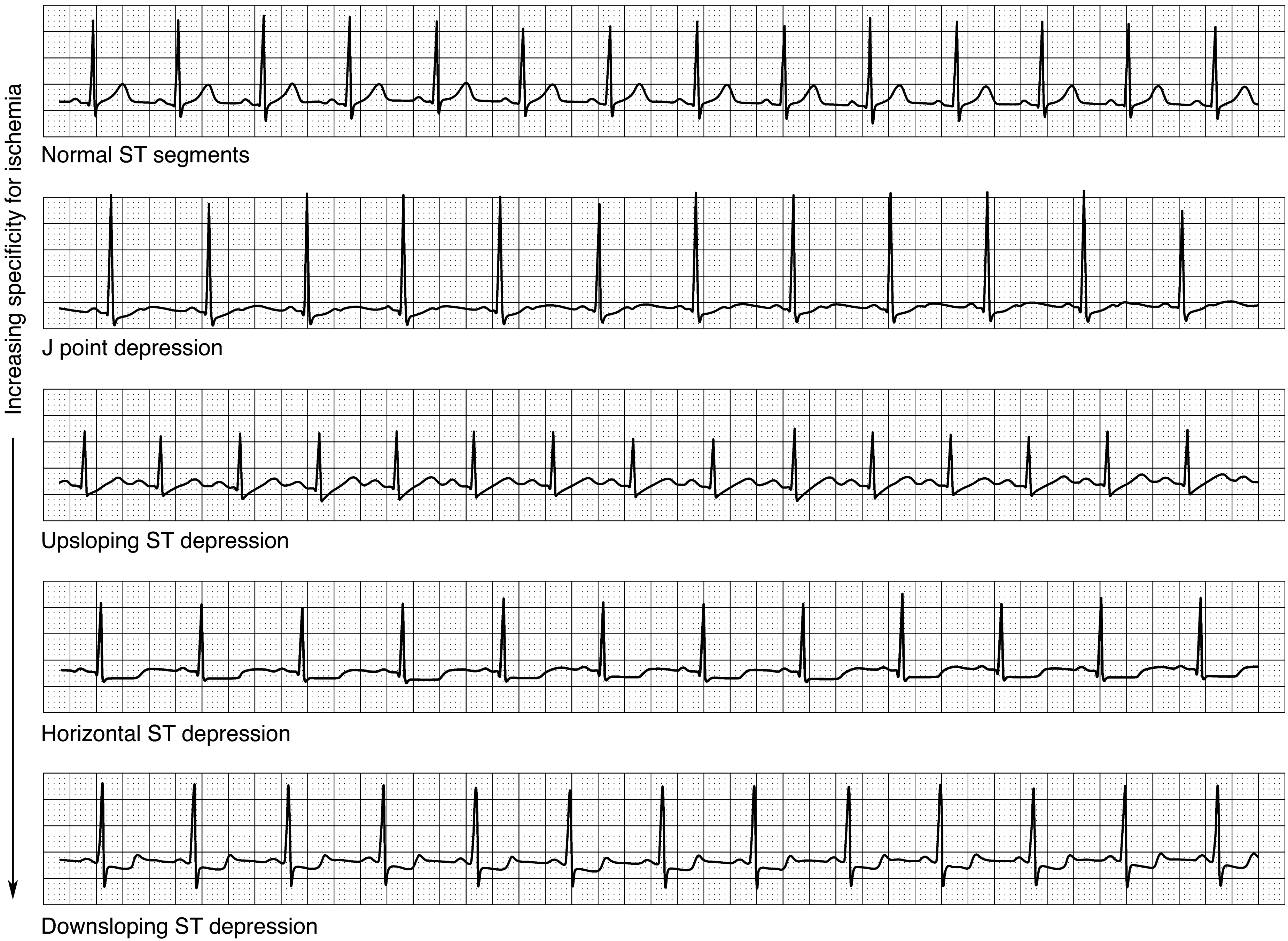


In this example, there is 2.0 mm of horizontal ST segment depression 80 msec from the J point

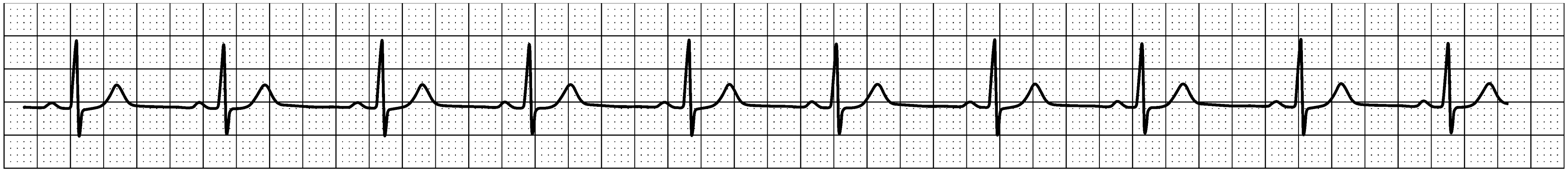
D. In exercise stress testing, 1 mm or more of horizontal or downsloping ST segment depression 80 msec from the J point is considered an ischemic response. (Day 4-02)

E. The specificity of ST segment and T wave changes is decreased in patients with resting abnormalities, particularly LBBB and LVH. (Day 4-03)

DAY 4-01

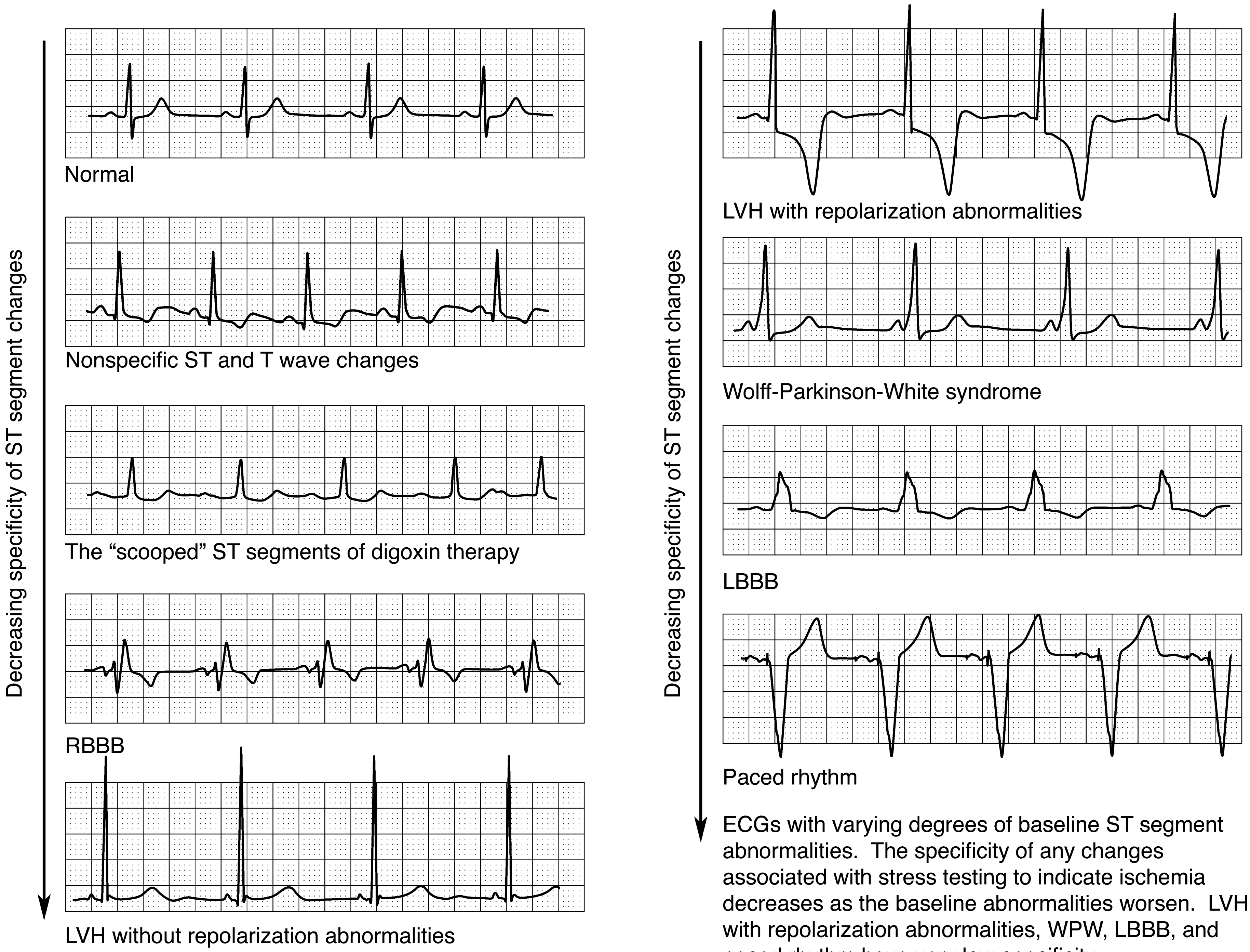

Increasing specificity for ischemia
Normal ST segments
J point depression
Upsloping ST depression
Horizontal ST depression
Downsloping ST depression

DAY 4-02



Lead II rhythm strip obtained prior to exercise stress testing showing normal ST segments

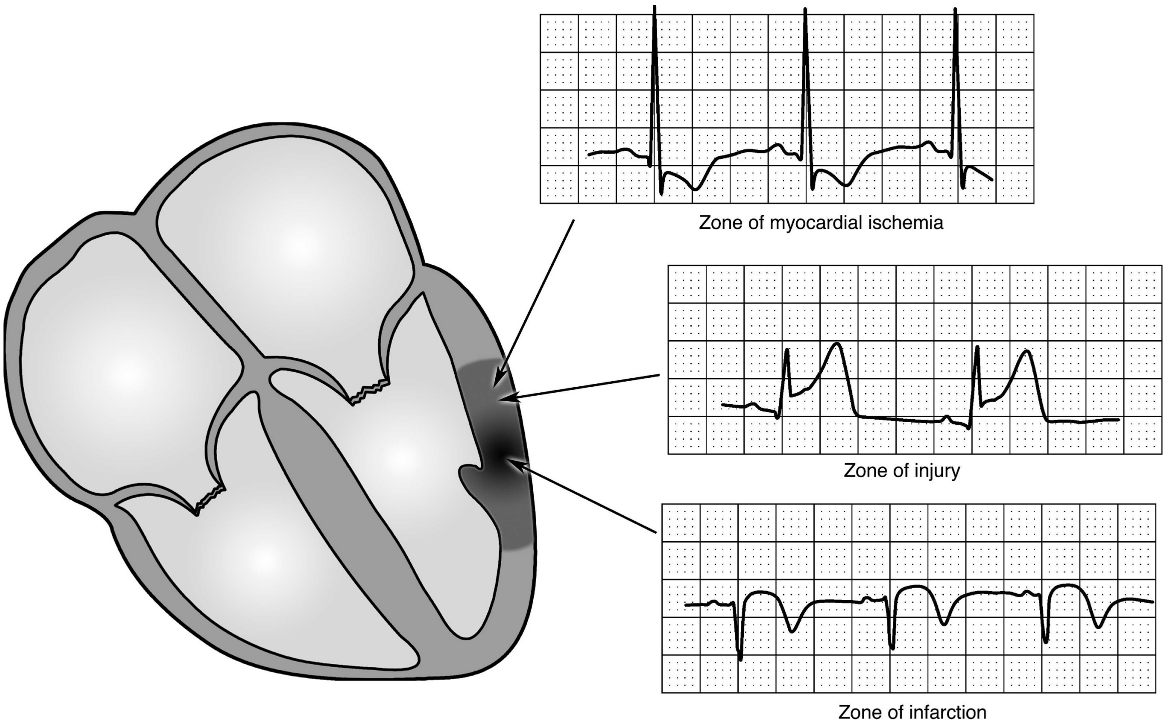
Lead II rhythm strip obtained at peak exertion showing downsloping ST segment depression consistent with ischemia



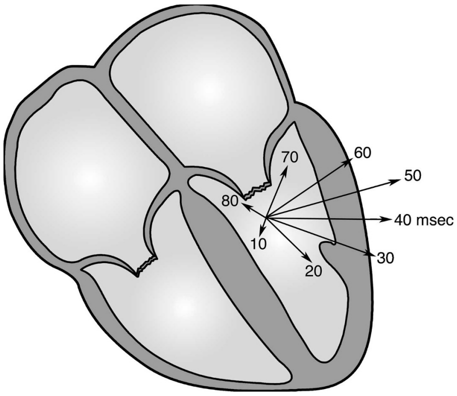
ECGs with varying degrees of baseline ST segment abnormalities. The specificity of any changes associated with stress testing to indicate ischemia decreases as the baseline abnormalities worsen. LVH with repolarization abnormalities, WPW, LBBB, and paced rhythm have very low specificity.

II. Myocardial infarction(MI)

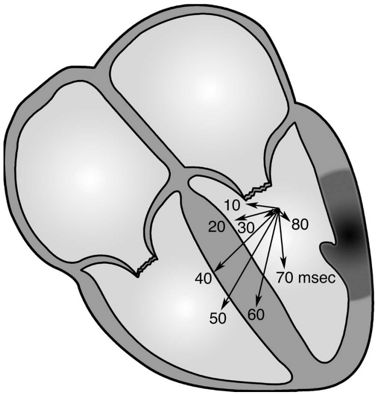
A. ECG patterns in infarction
1. A zone of ischemia typically produces ST segment depression.
2. A zone of injury produces ST segment elevation.
3. A zone of infarction produces a large Q wave in the QRS complex.

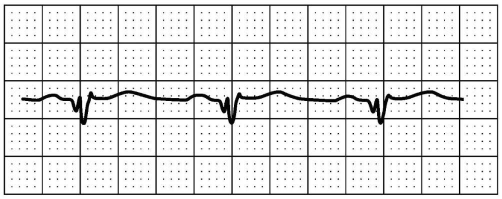


B. Genesis of the Q wave in infarction
   1. The normal situation
      a. For example, in Lead I, the QRS complex begins with a small Q wave because left ventricular depolarization begins in the septum and the electrical forces are directed away from Lead I.
      b. The small Q wave is rapidly succeeded by forces directed inferiorly and laterally, resulting in a large R wave in Lead I.
   2. The infarct situation
      a. If there is a lateral myocardial infarction, however, the electrical vectors in the lateral direction are lost, the forces directed medially are unbalanced.
      b. A large Q wave results in Lead I.



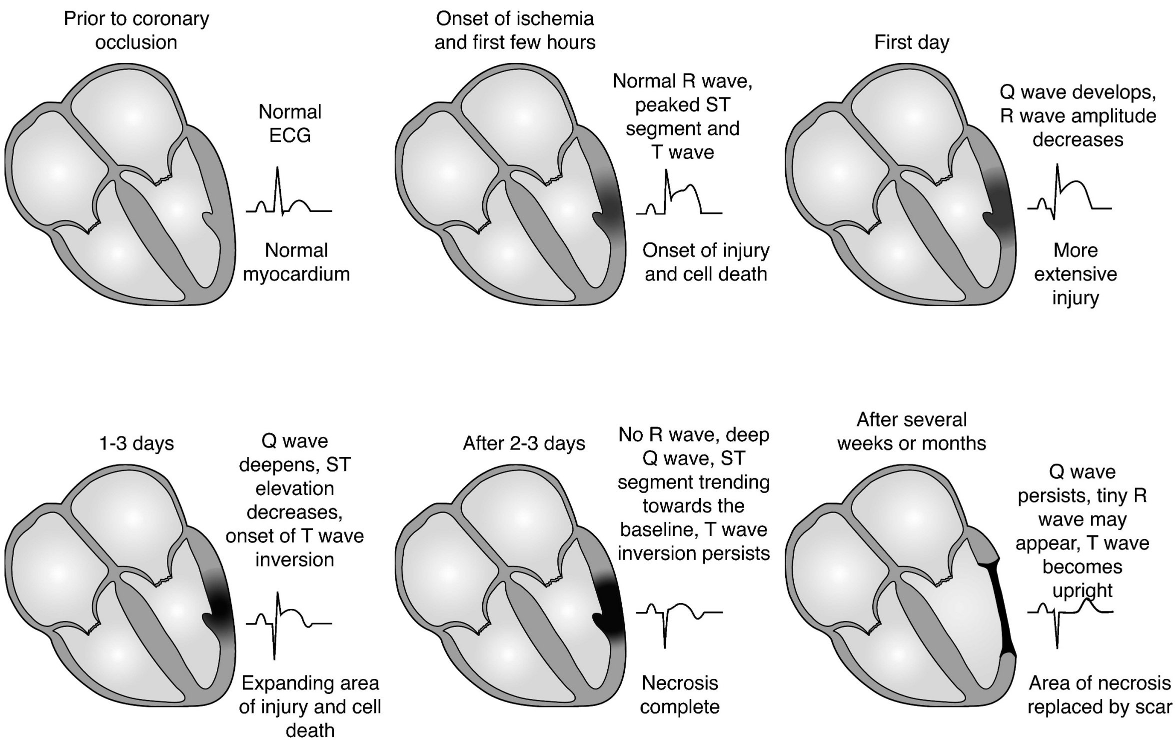
Lead I ECG with normal progression of the electrical vectors. The QRS starts with a tiny septal Q wave and then is nearly entirely positive.



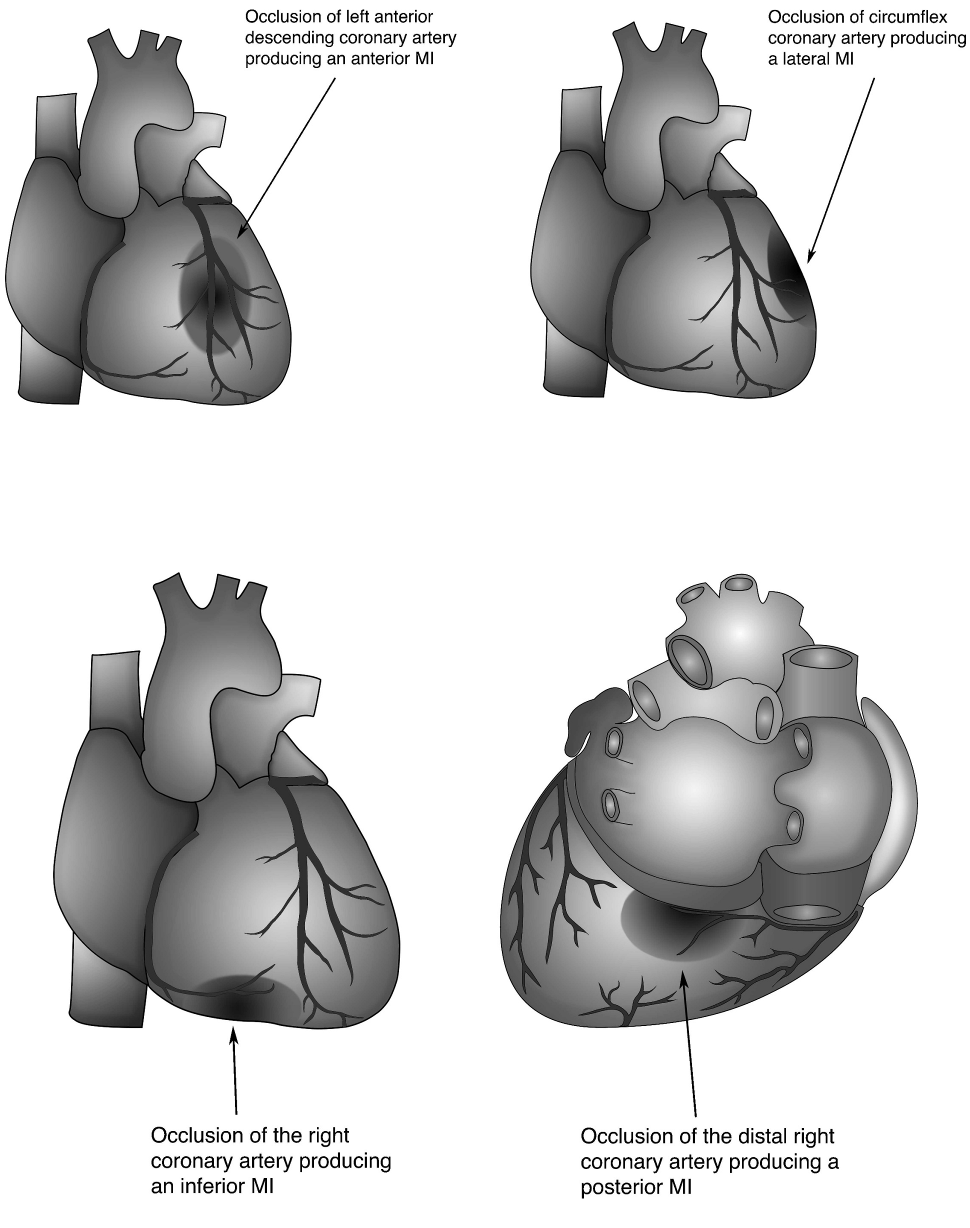


Lead I ECG in a patient with a lateral myocardial infarction. Note that loss of electrically active myocardium in the lateral wall has shifted the vectors away from that direction, resulting in a Q wave in the ECG.

III. The time course of myocardial and ECG changes during infarction

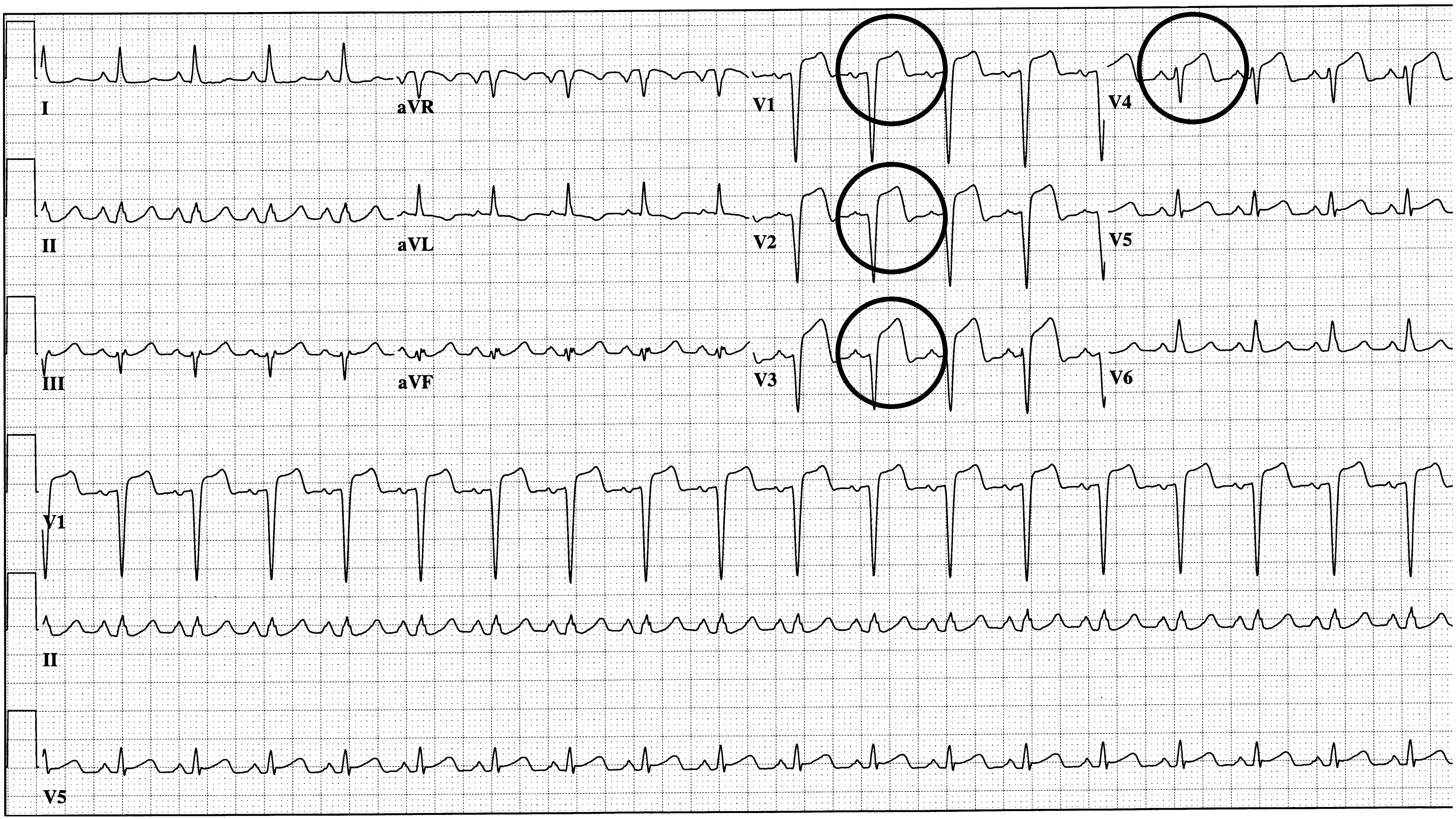


IV. Anatomical and ECG locations of MI (Day 4-04) (Day 4-05)



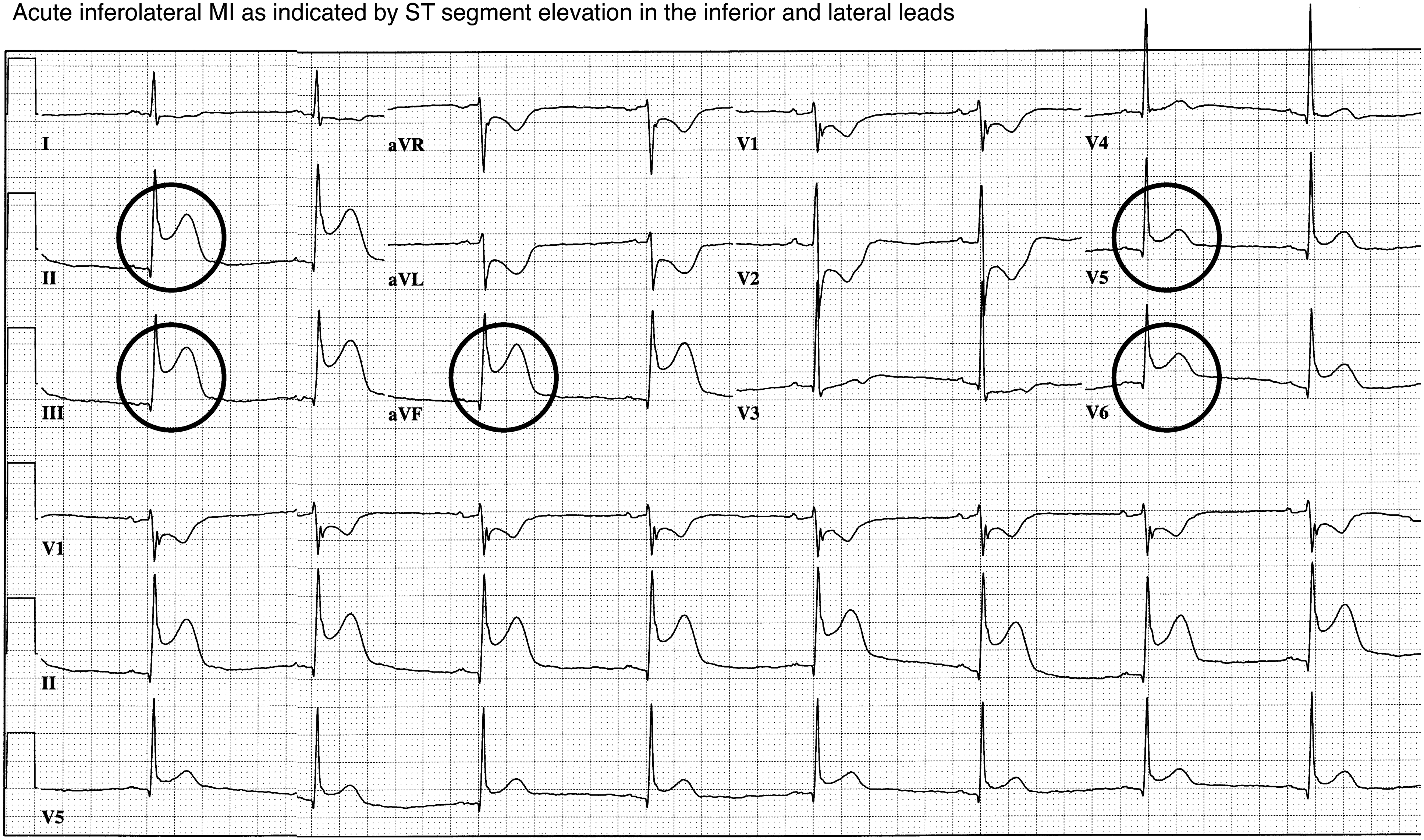
DAY 4-04

Acute anterior MI as indicated by ST segment elevation in the anterior leads



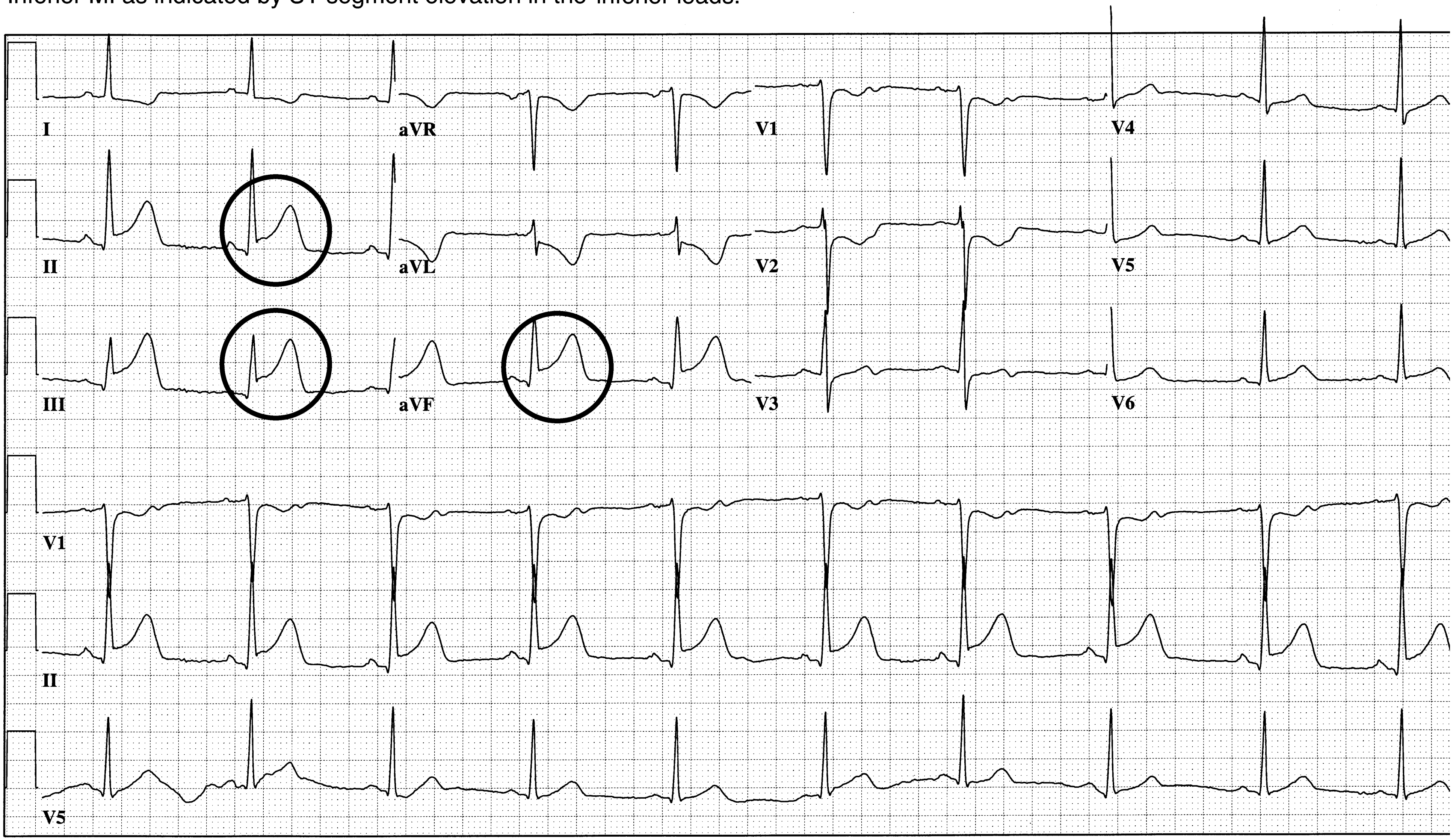
DAY 4-05

Acute inferolateral MI as indicated by ST segment elevation in the inferior and lateral leads



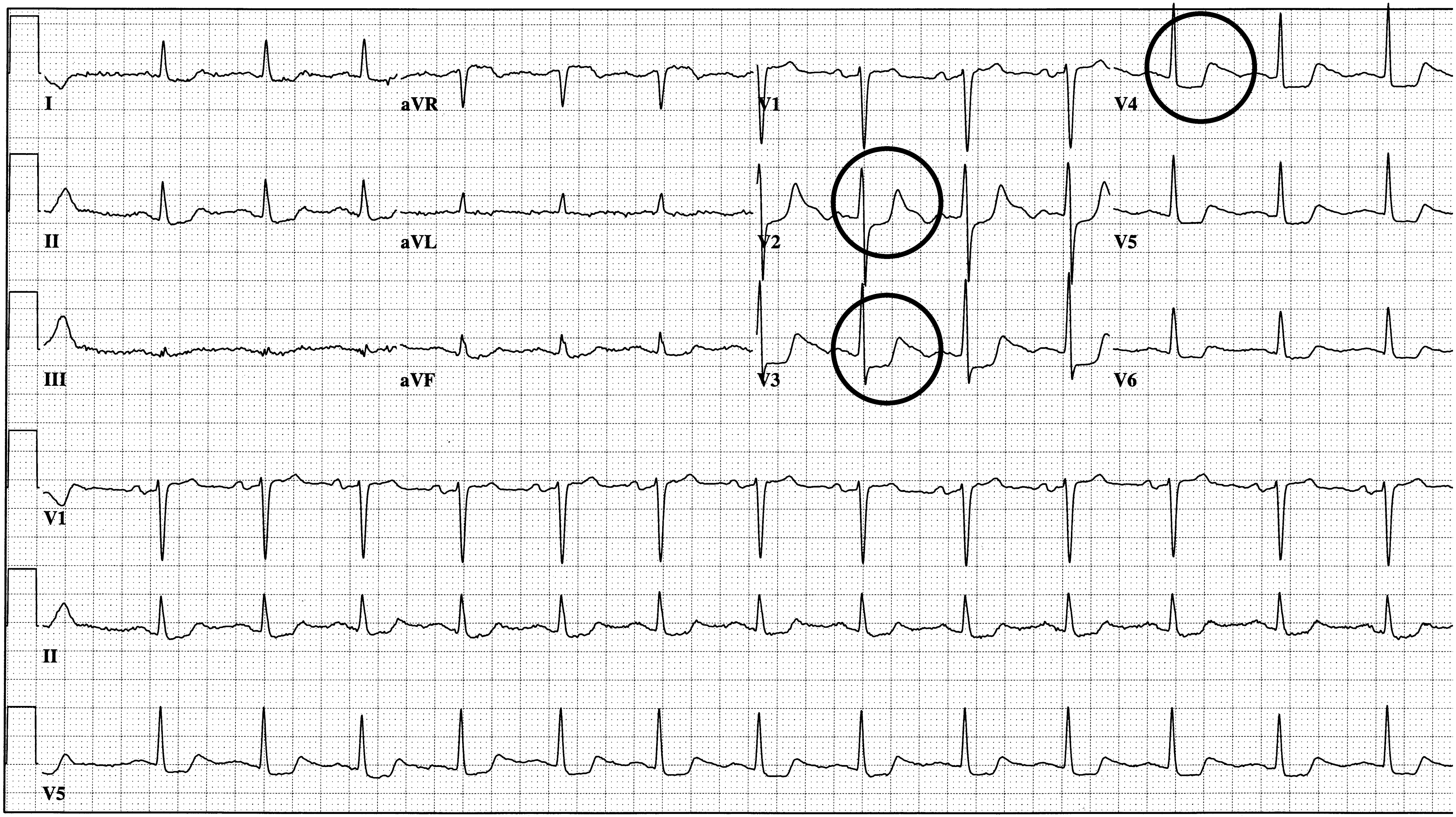
DAY 4-06

Inferior MI as indicated by ST segment elevation in the inferior leads.



DAY 4-07

Posterior MI as indicated by ST segment depression and tall R waves in the anterior leads

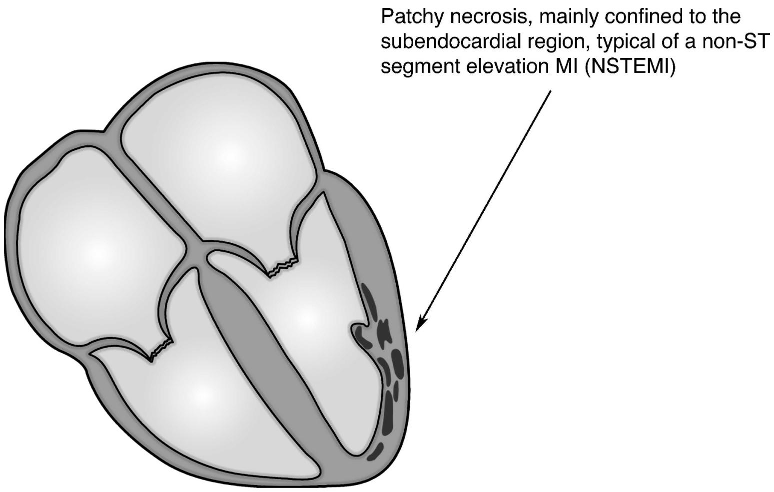


V. Non-ST-segment elevation MI (NSTEMI) (Day 4-08)

A. About half of the 750,000 MIs that occur annually in the U.S. do not develop new Q waves.

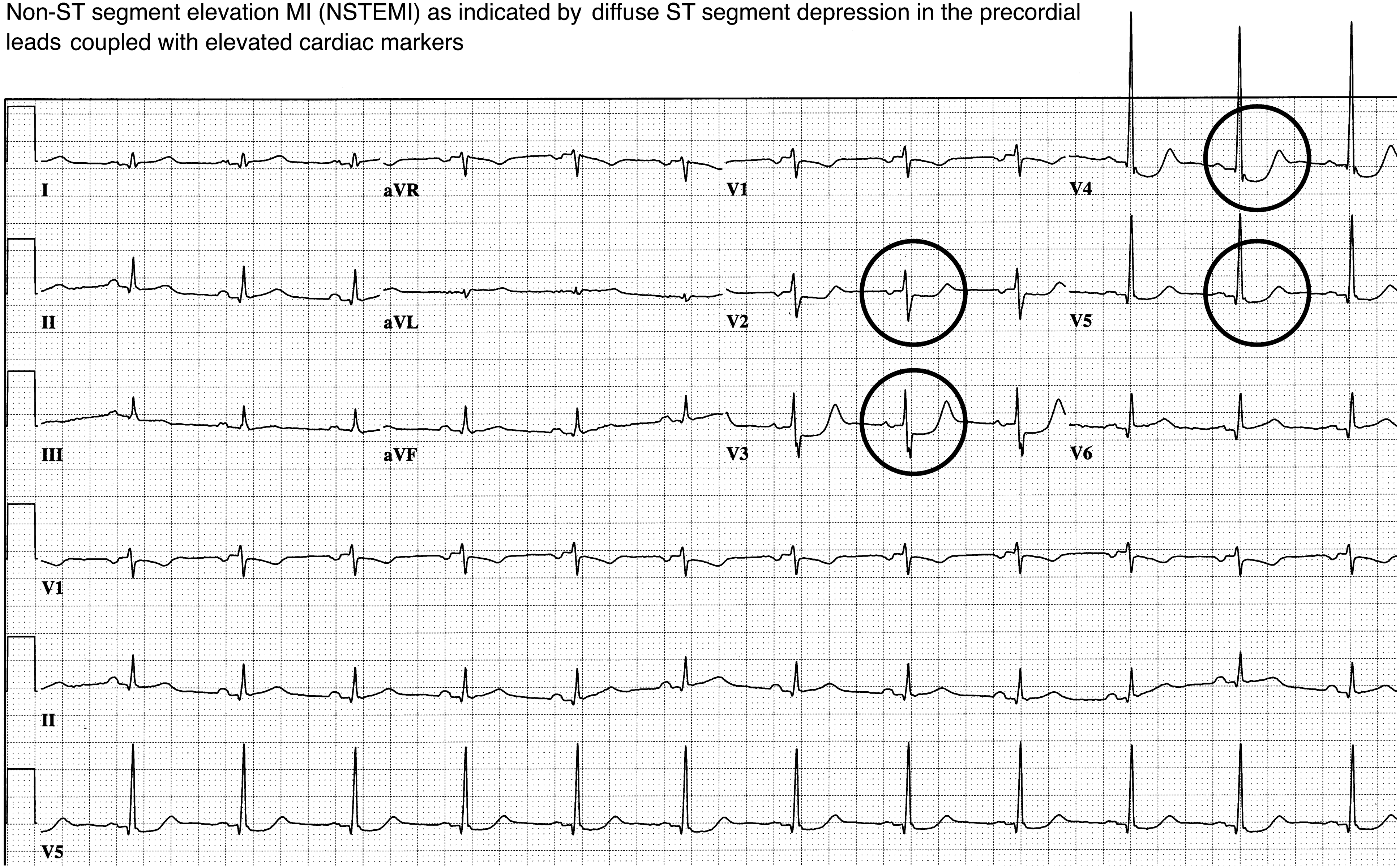
B. Usually there are ST segment and T wave changes, but about 20% of NSTEMIs have no obvious ECG abnormalities and the diagnosis of MI is based on the clinical presentation and elevated cardiac markers.

C. Anatomically, NSTEMIs are frequently associated with patchy subendocardial necrosis.



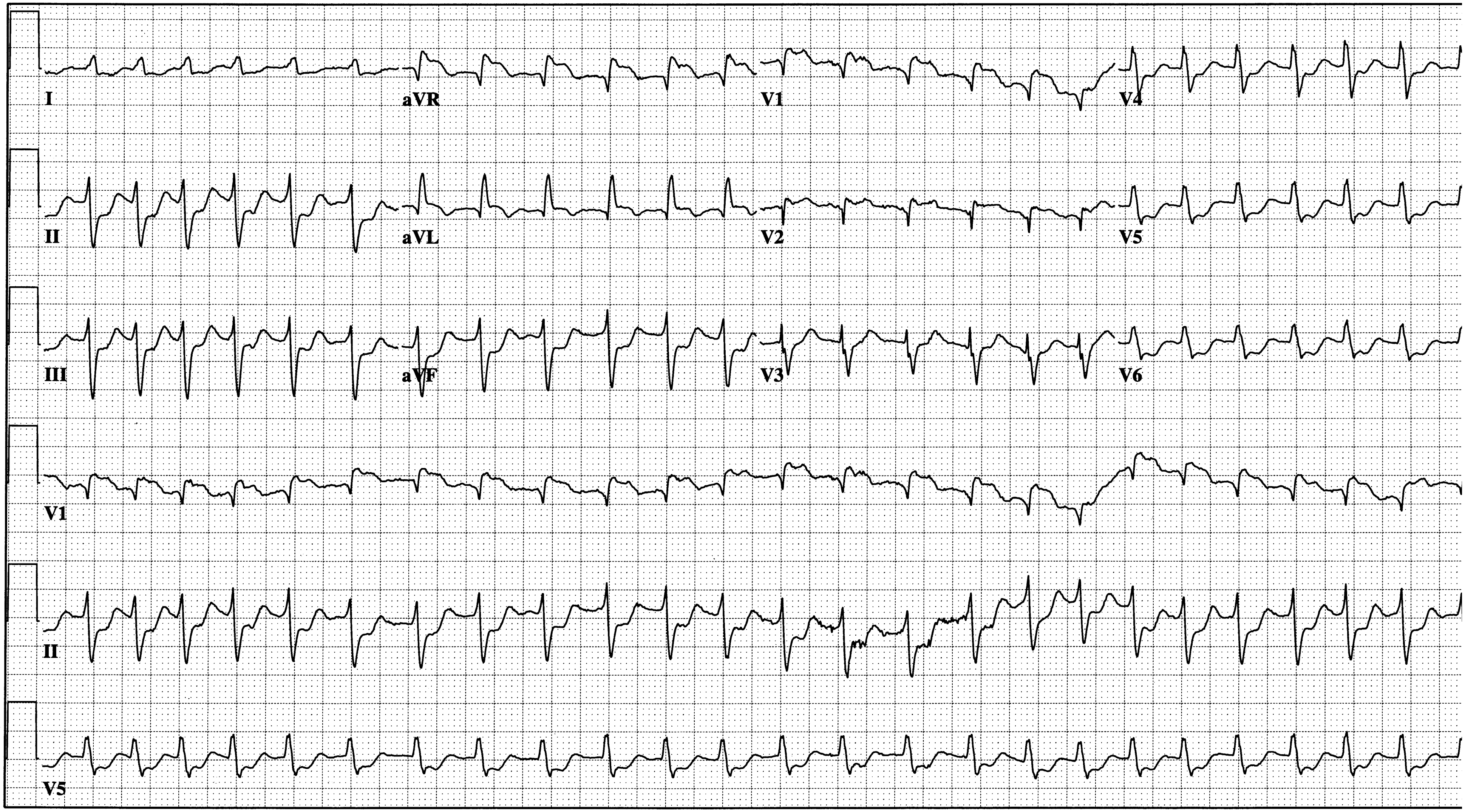
DAY 4-08

Non-ST segment elevation MI (NSTEMI) as indicated by diffuse ST segment depression in the precordial leads coupled with elevated cardiac markers



Sample Tracings
ECG 1

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG 2

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

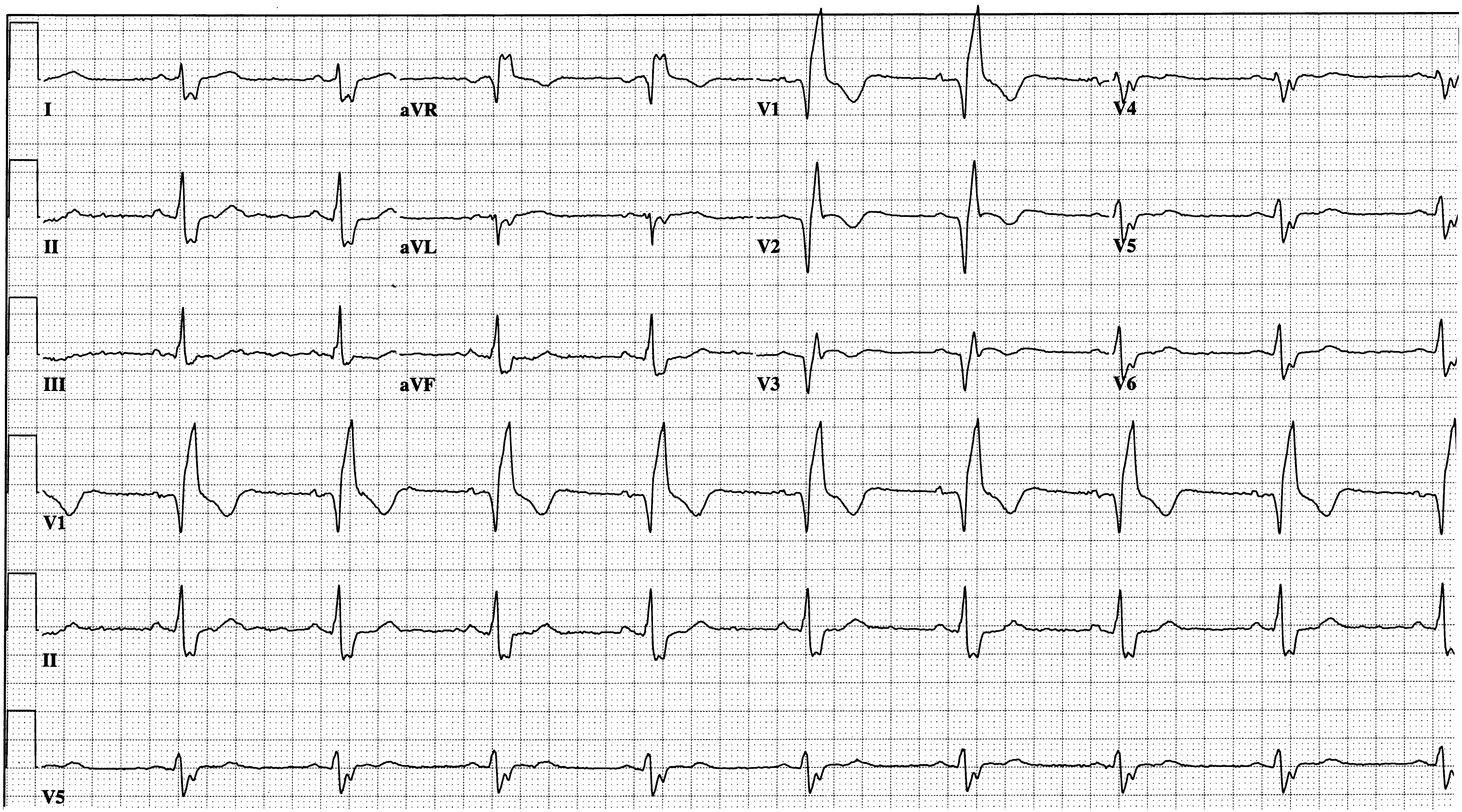
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 3

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

ST segment: ____________________

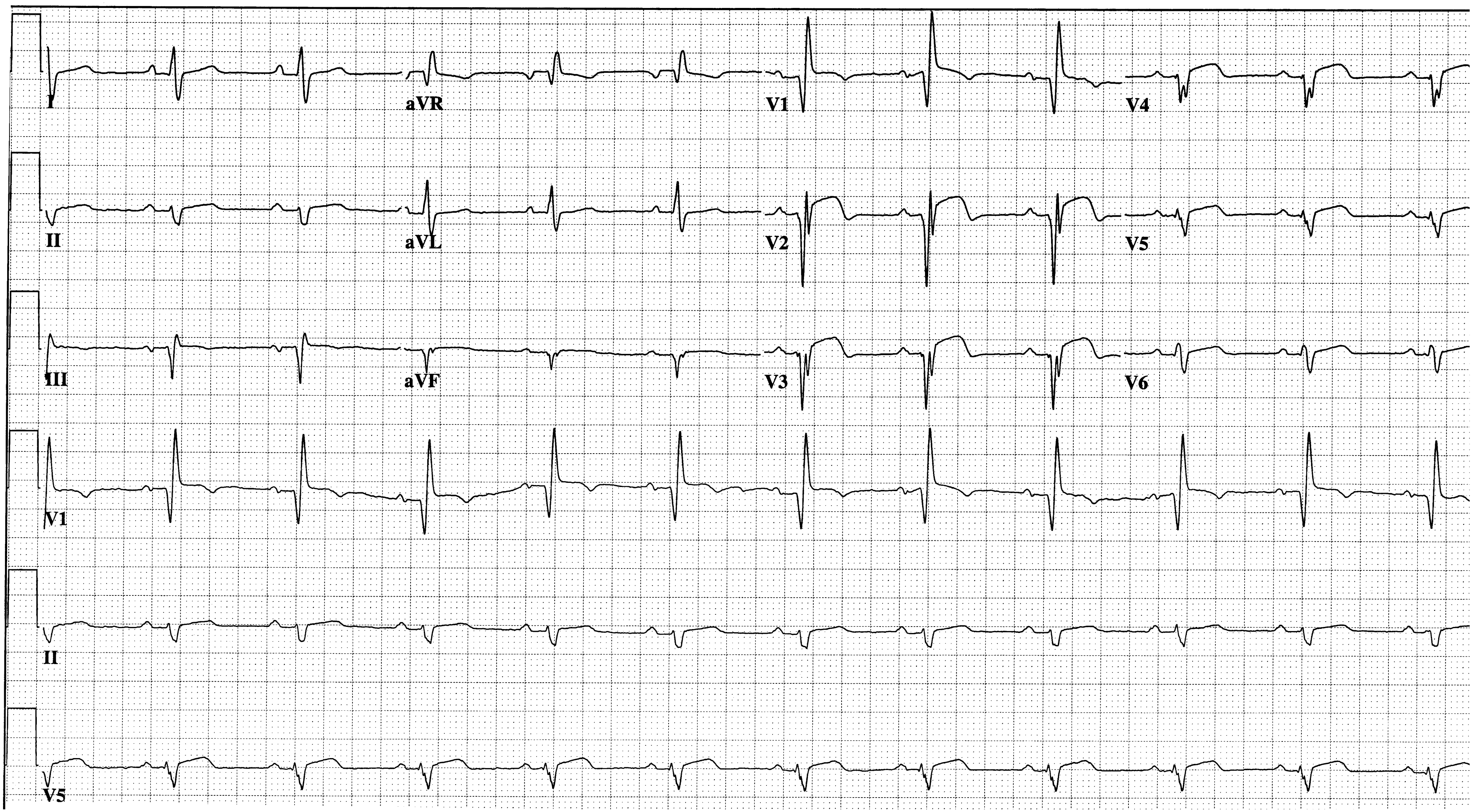
T wave: ____________________

QT interval: ____________________

U wave: ____________________

Diagnosis: ____________________

____



ECG 4

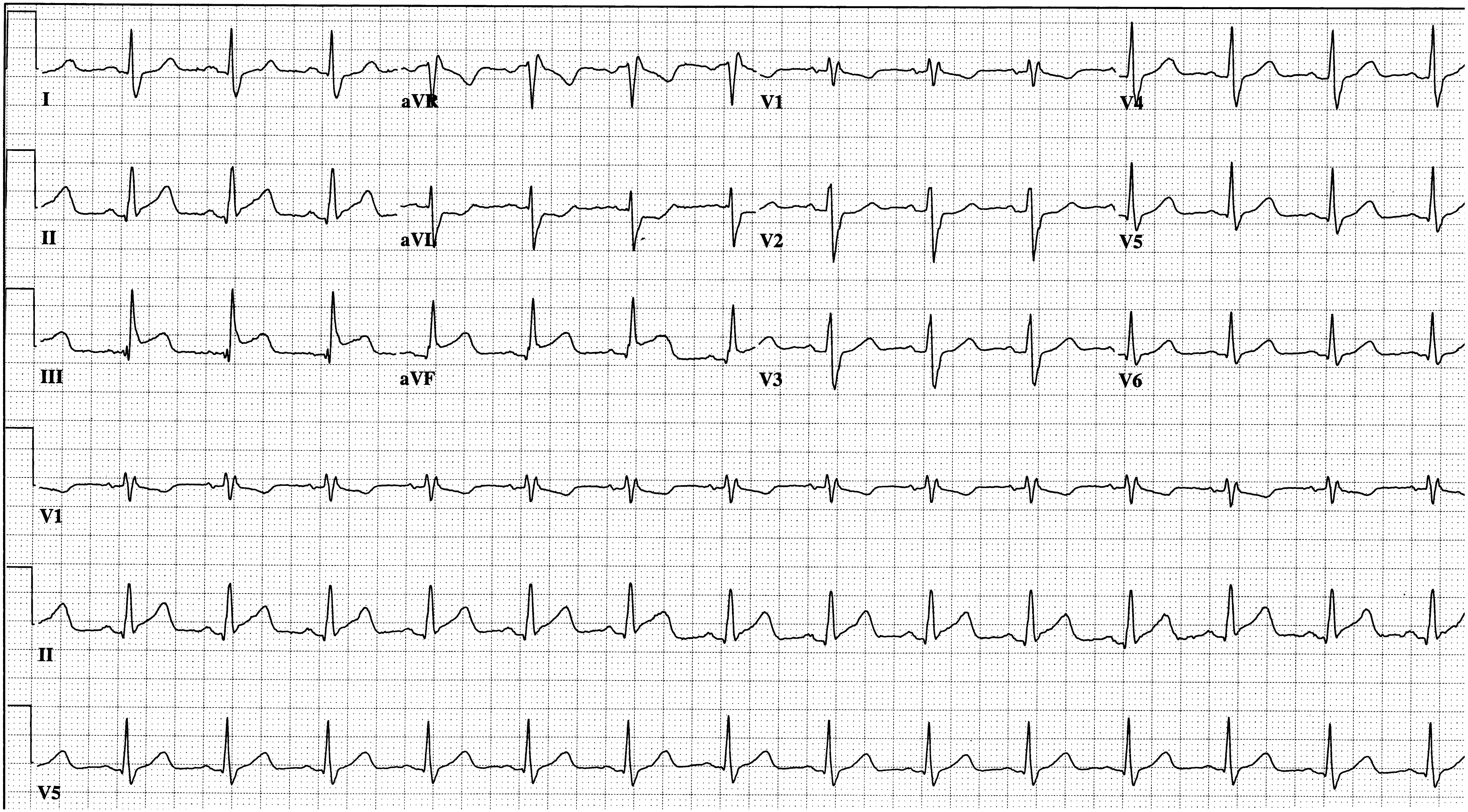
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG 5

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

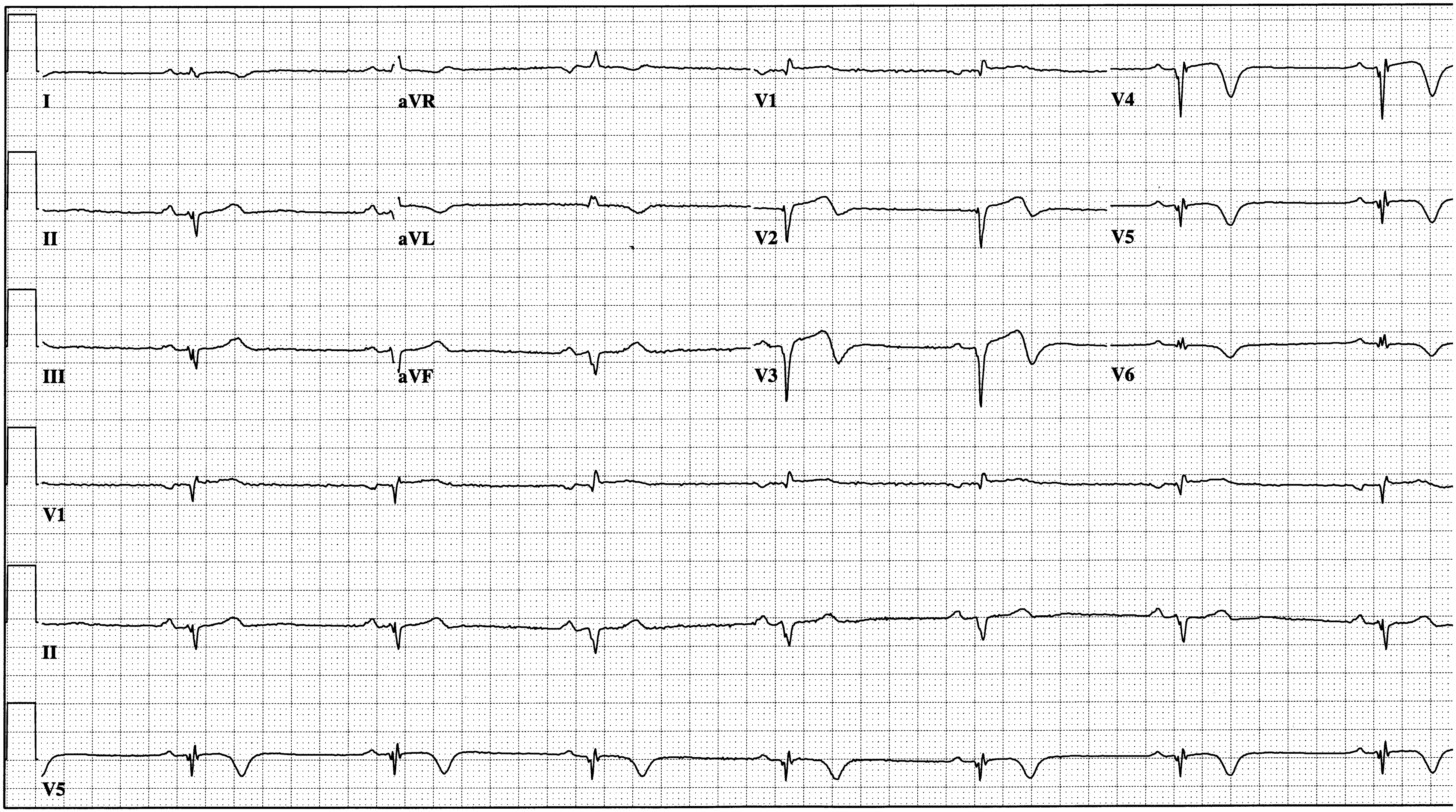
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 6

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

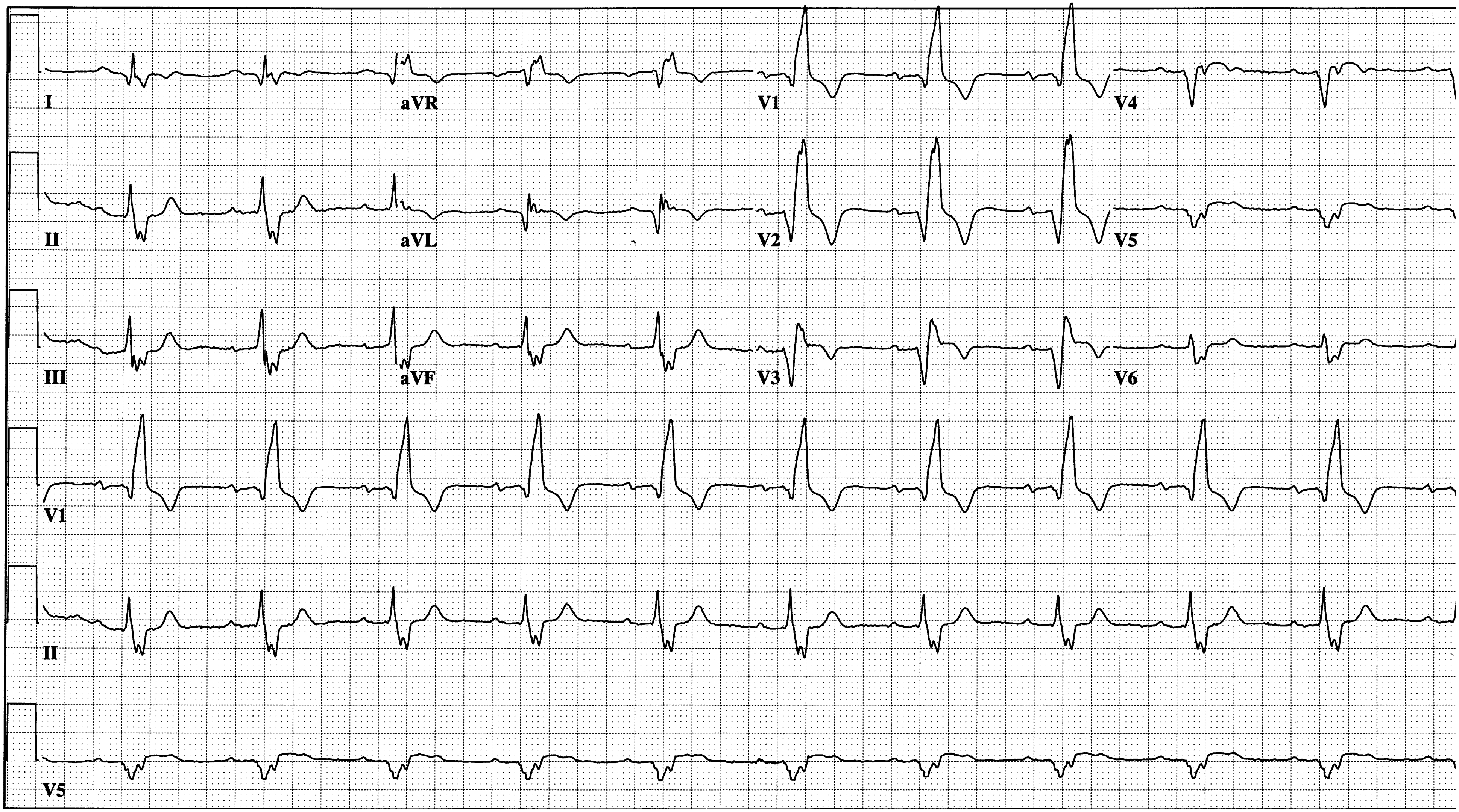
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 7

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

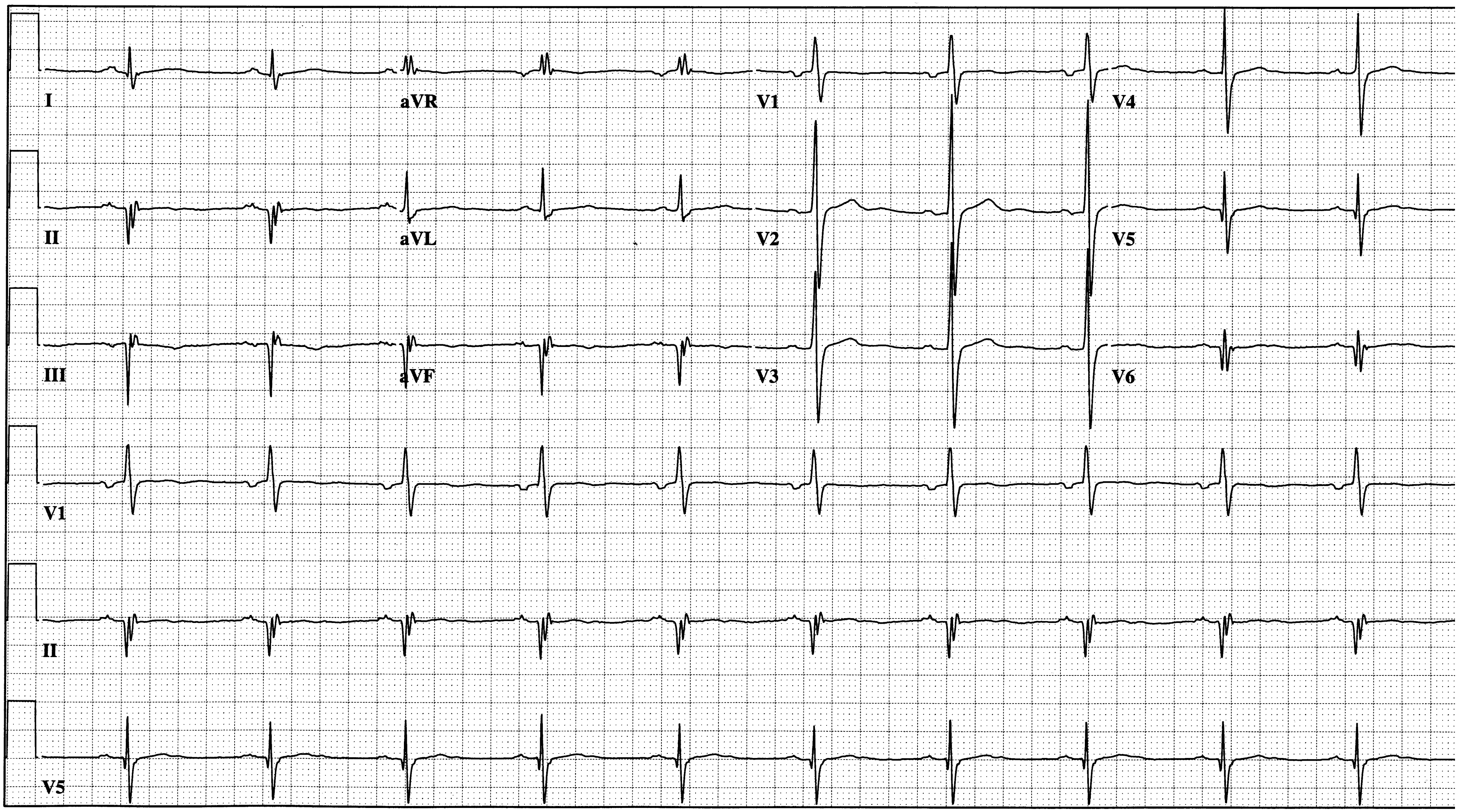
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 8

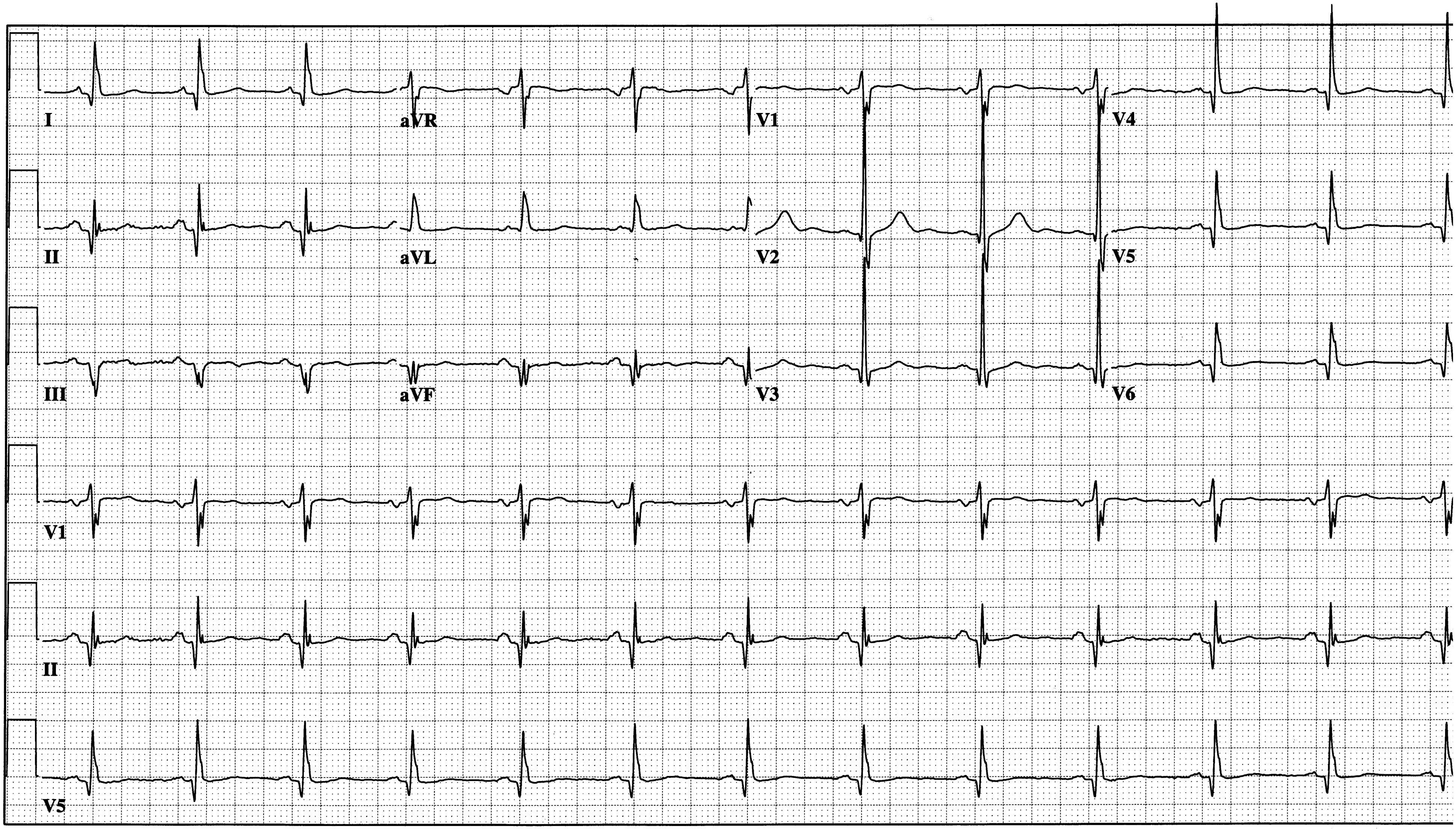
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

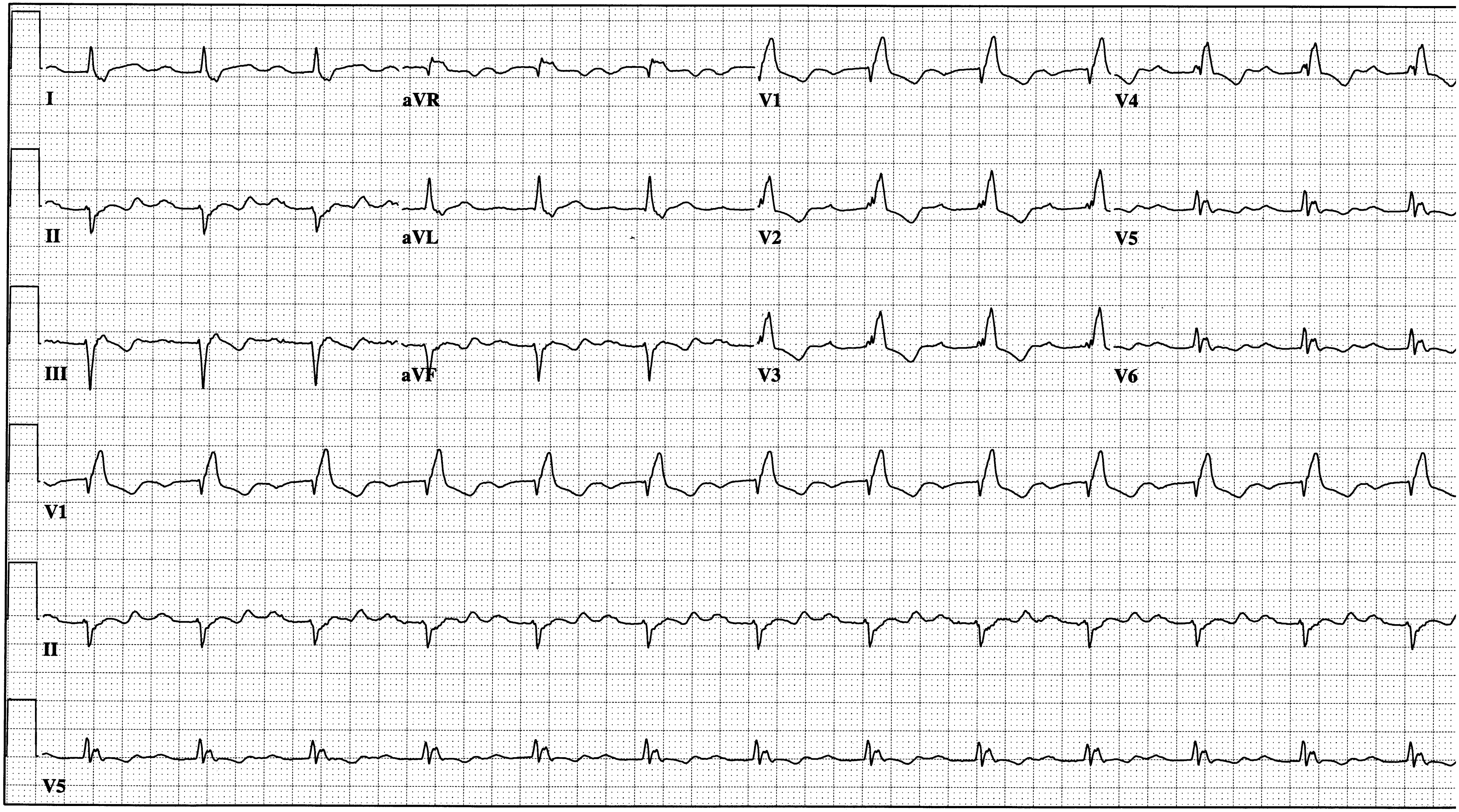
P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



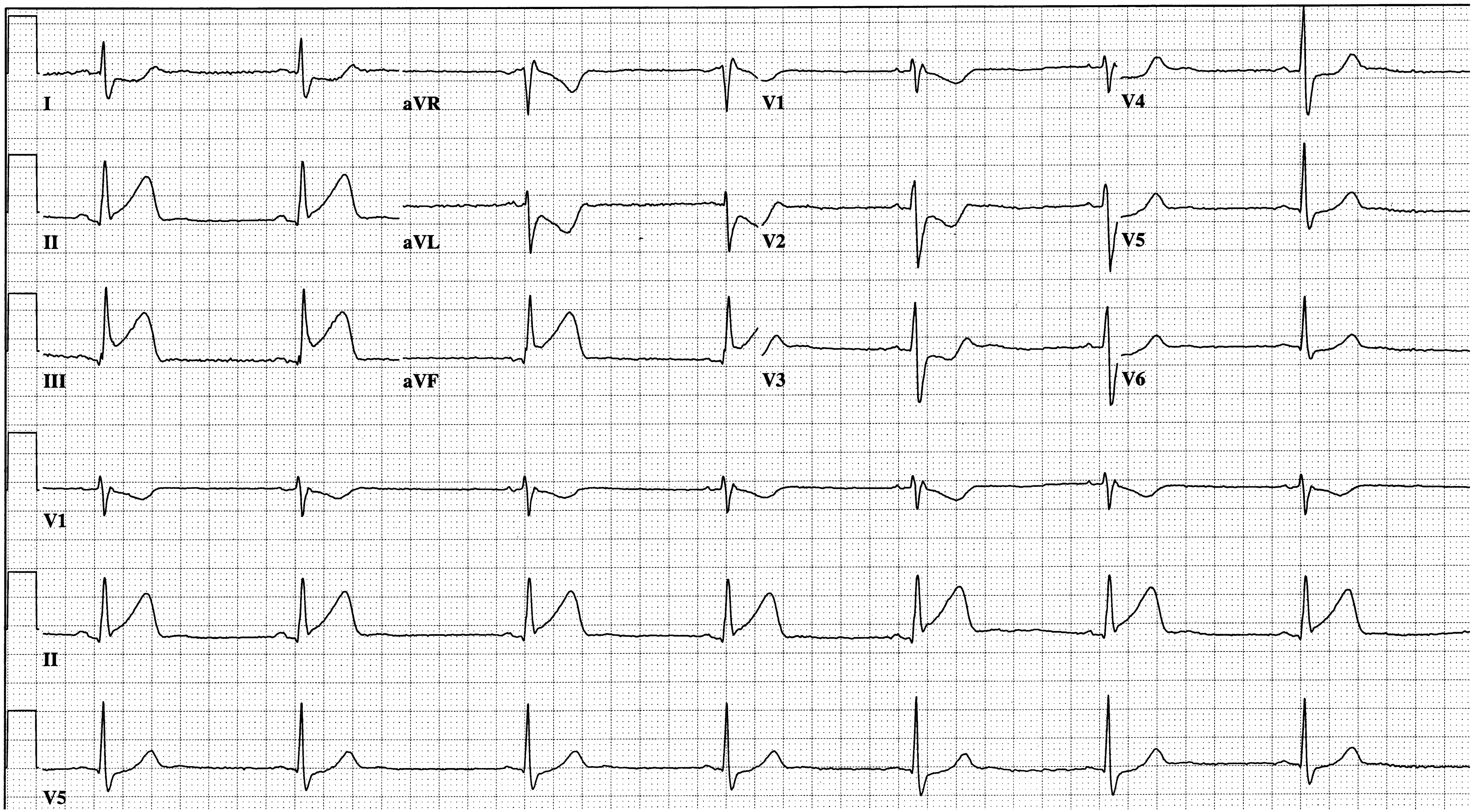
ECG 9

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG 10

Atrial rate: ________	QRS complex:	ST segment: ________
Ventricular rate: ________	Axis: ________	T wave: ________
Rhythm: ________	Duration: ________	QT interval: ________
P wave: ________	Voltage: ________	U wave: ________
PR interval: ________	Morphology: ________	Diagnosis: ________



ECG 11

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

ST segment: ______

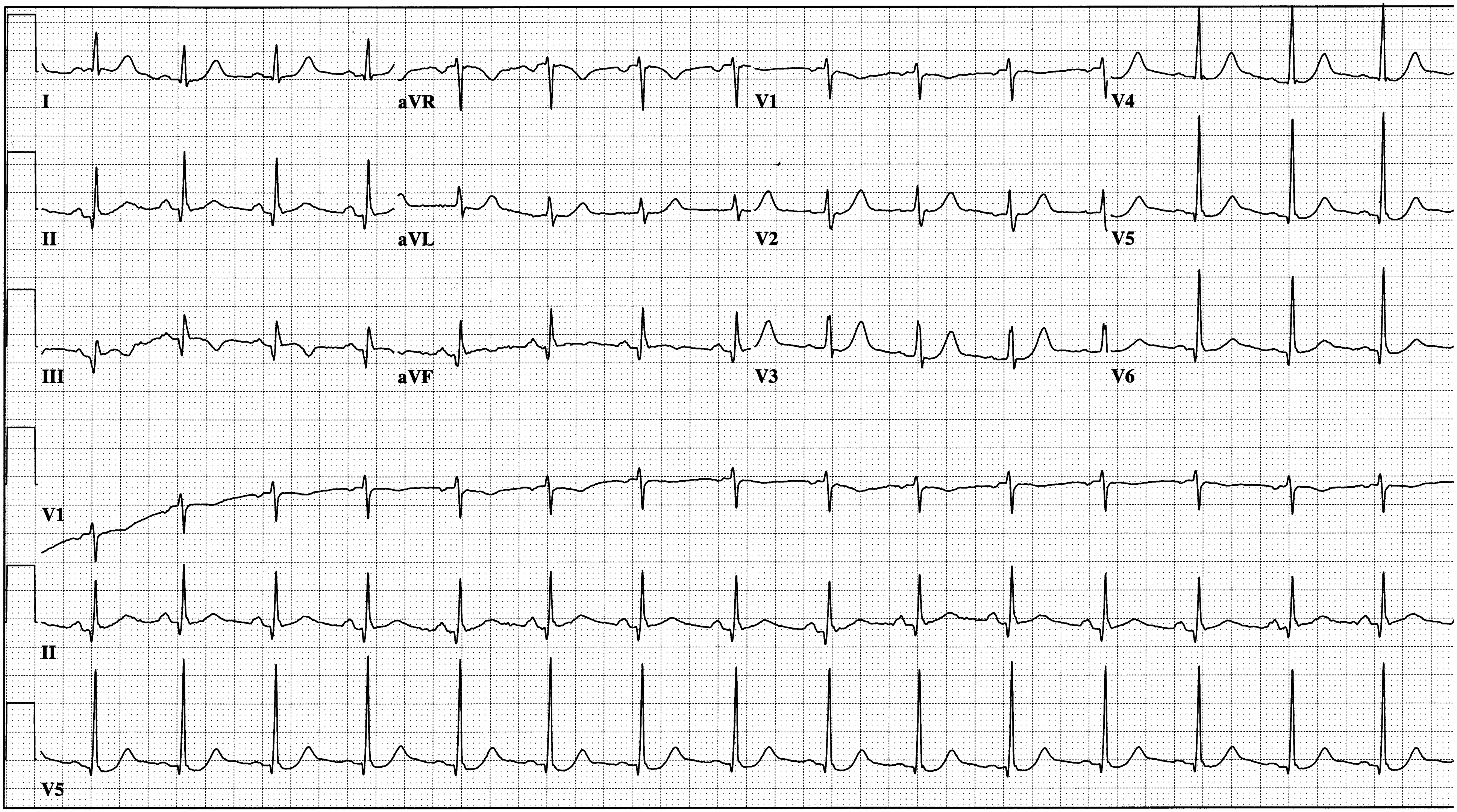
T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______

______



ECG 12

Atrial rate: ____________

Ventricular rate: ____________

Rhythm: ____________

P wave: ____________

PR interval: ____________

QRS complex:

Axis: ____________

Duration: ____________

Voltage: ____________

Morphology: ____________

ST segment: ____________

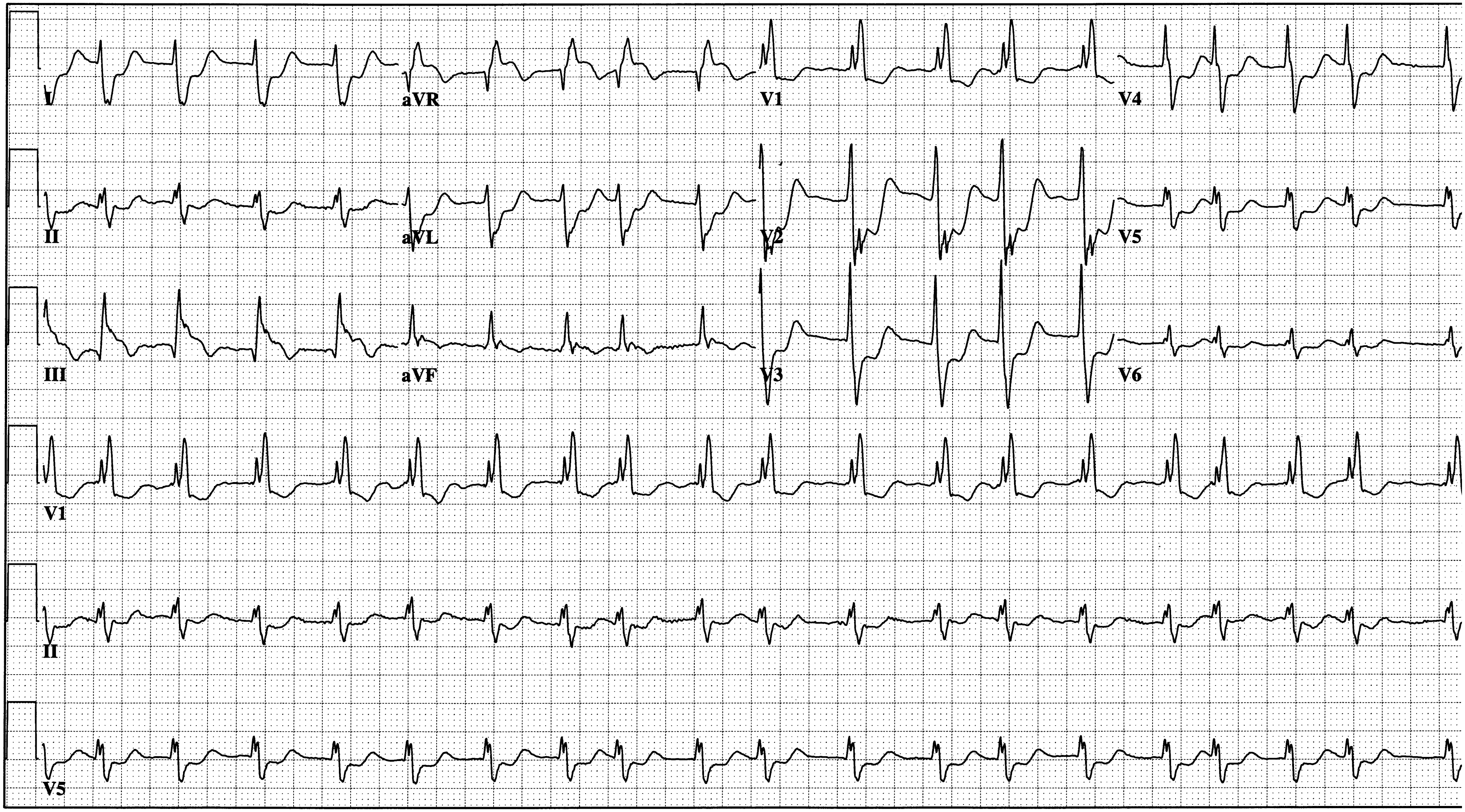
T wave: ____________

QT interval: ____________

U wave: ____________

Diagnosis: ____________

____



ECG 13

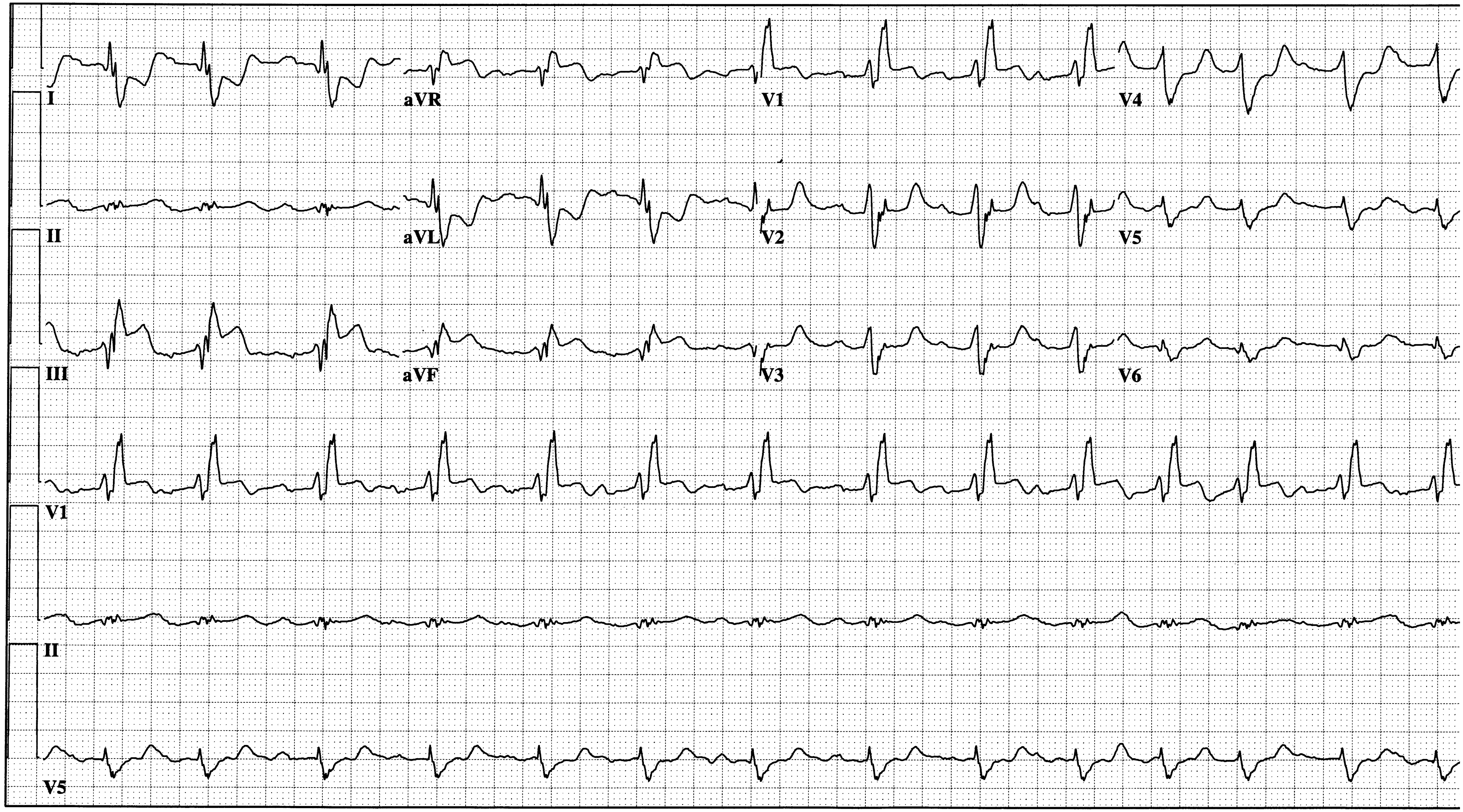
Atrial rate: ______________ QRS complex: ST segment: ______________

Ventricular rate: ______________ Axis: ______________ T wave: ______________

Rhythm: ______________ Duration: ______________ QT interval: ______________

P wave: ______________ Voltage: ______________ U wave: ______________

PR interval: ______________ Morphology: ______________ Diagnosis: ______________



ECG 14

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

ST segment: ____________________

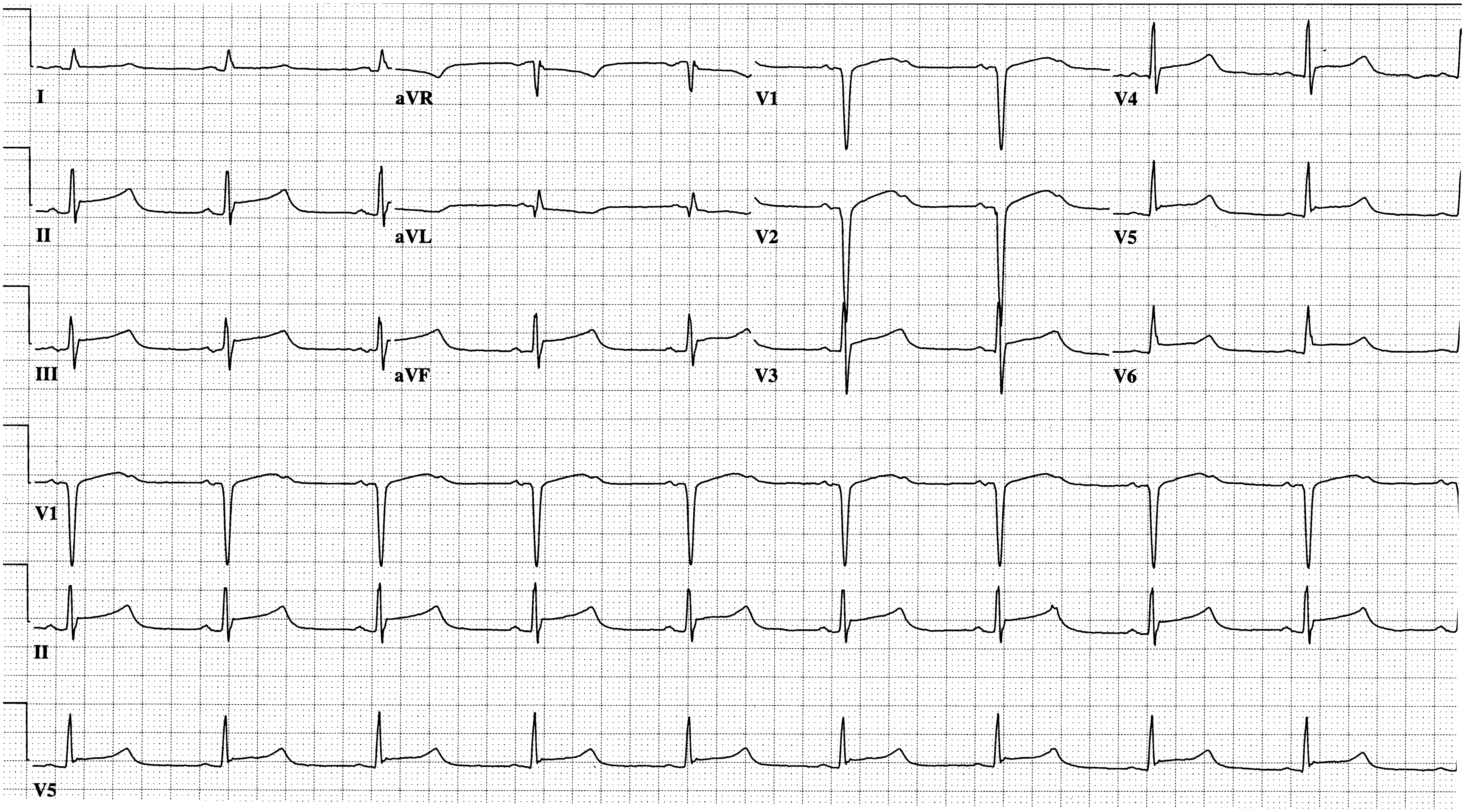
T wave: ____________________

QT interval: ____________________

U wave: ____________________

Diagnosis: ____________________

____



ECG 15

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

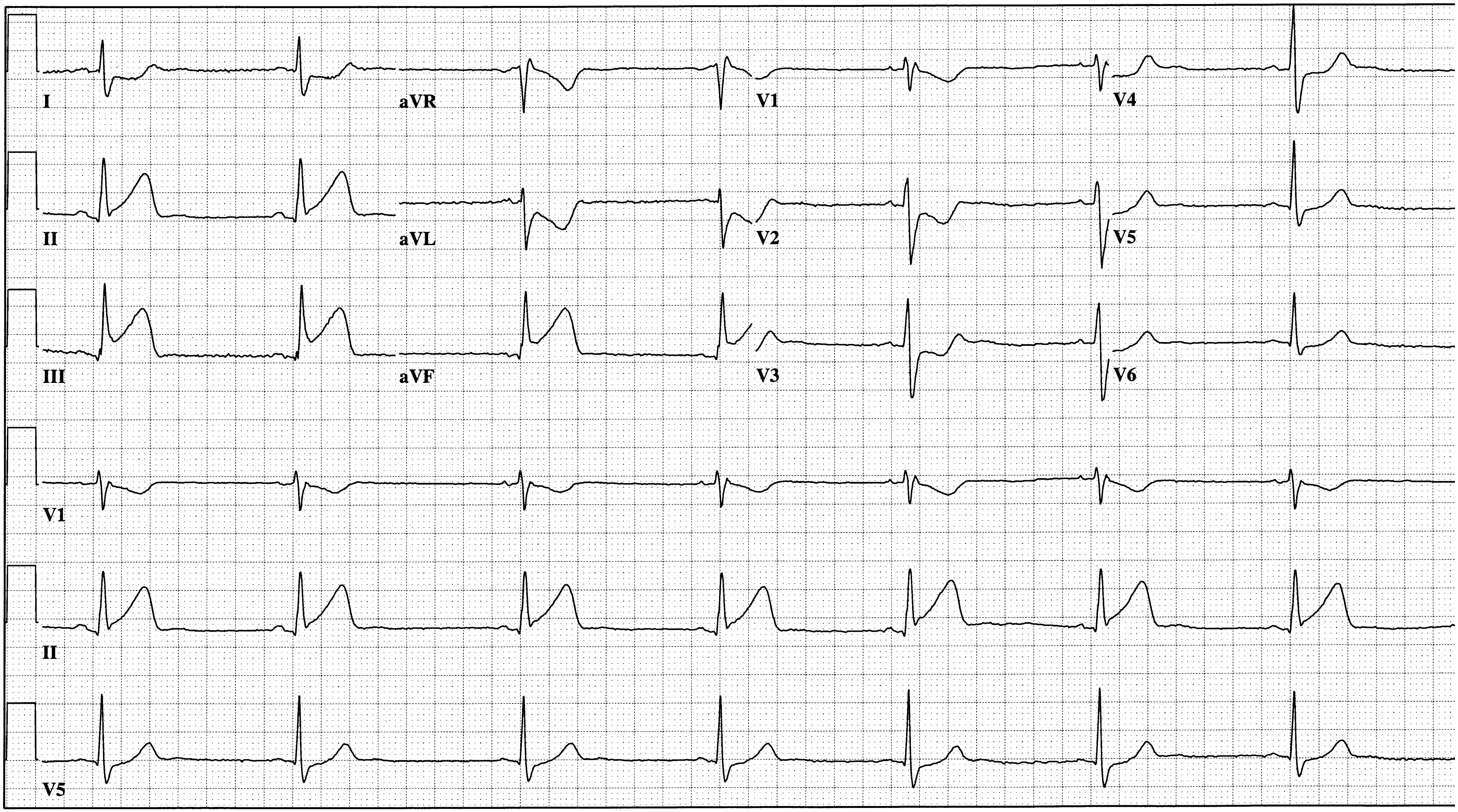
ST segment: ______

T wave: ______

QT interval: ______

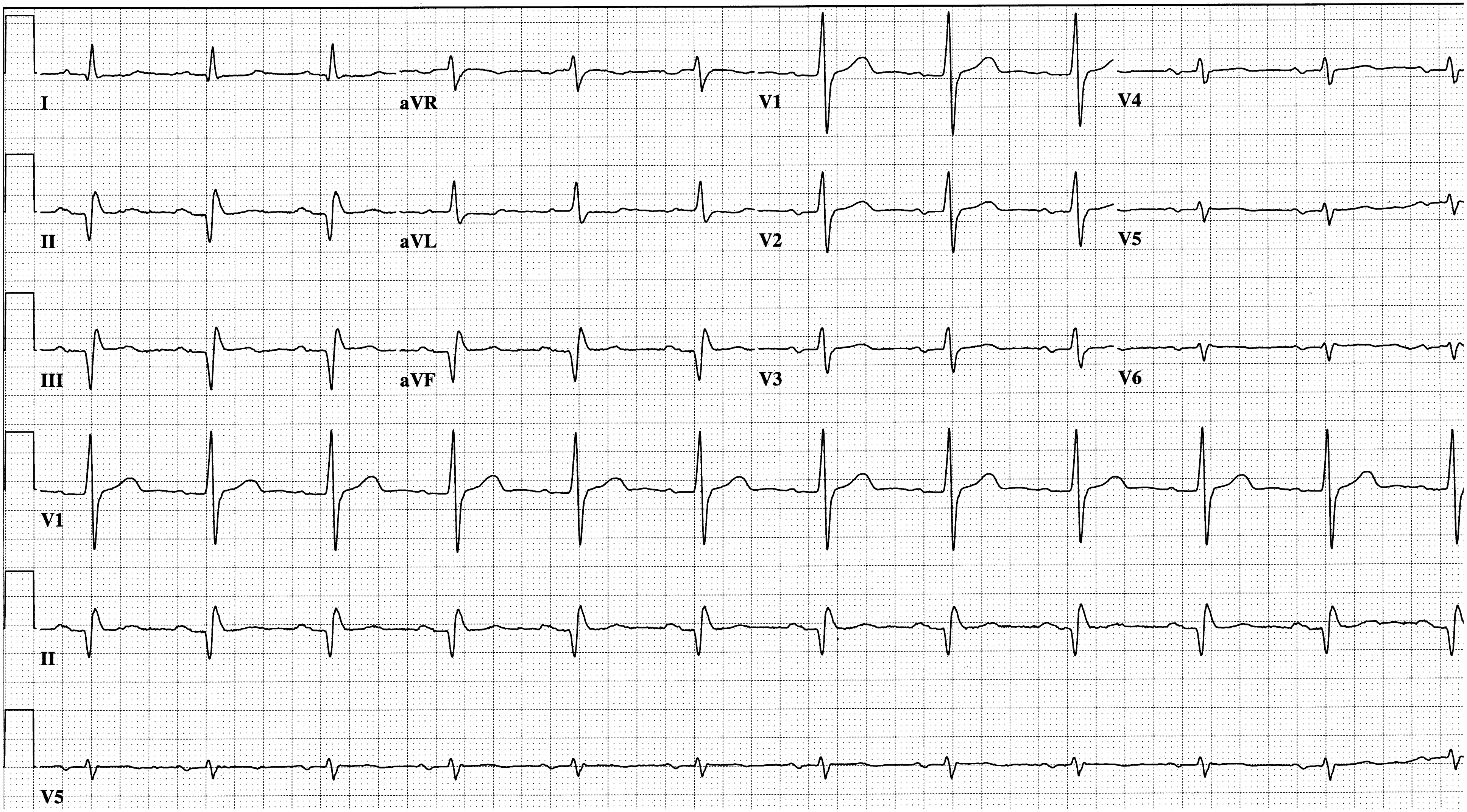
U wave: ______

Diagnosis: ______



ECG 16

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG 17

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

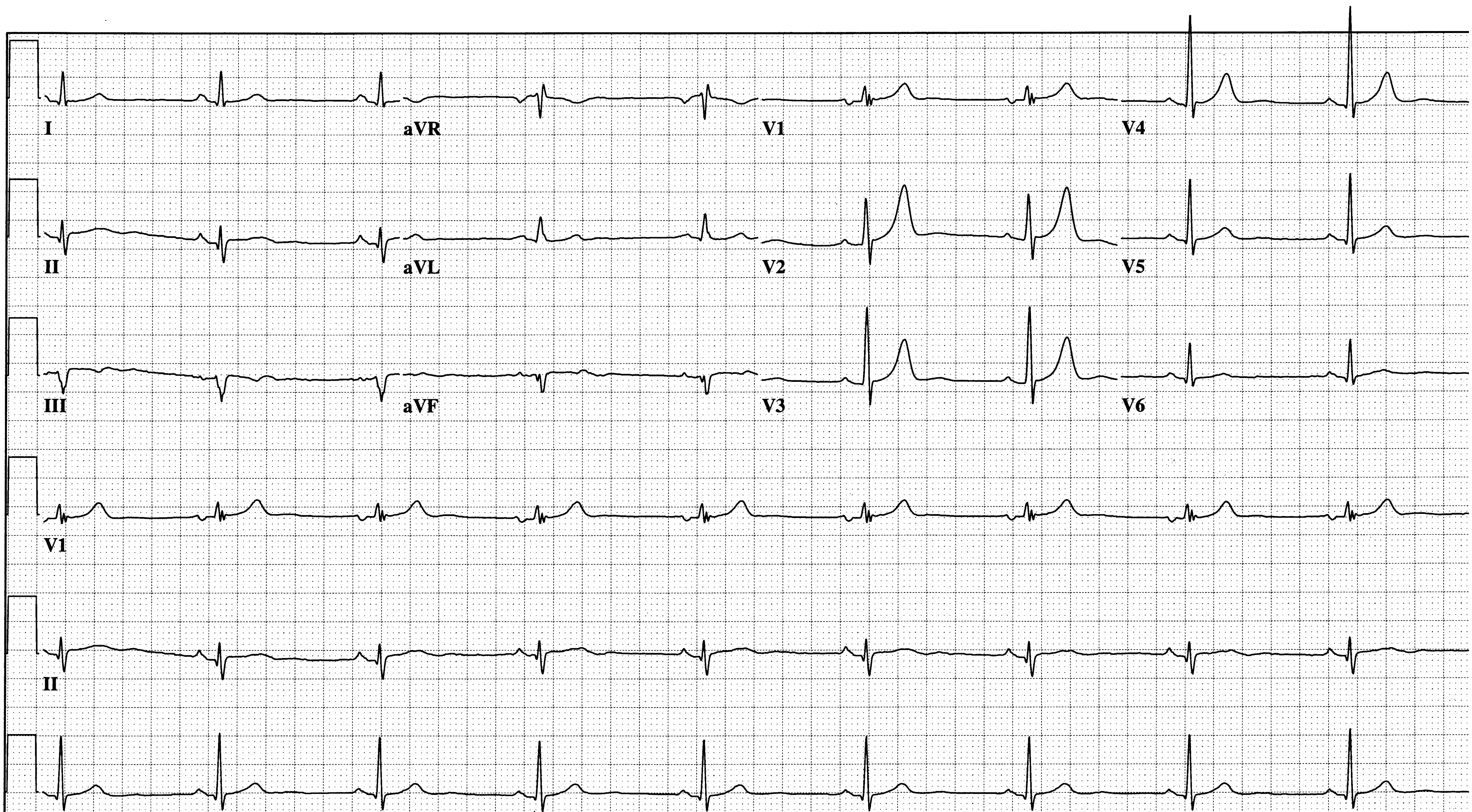
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 18

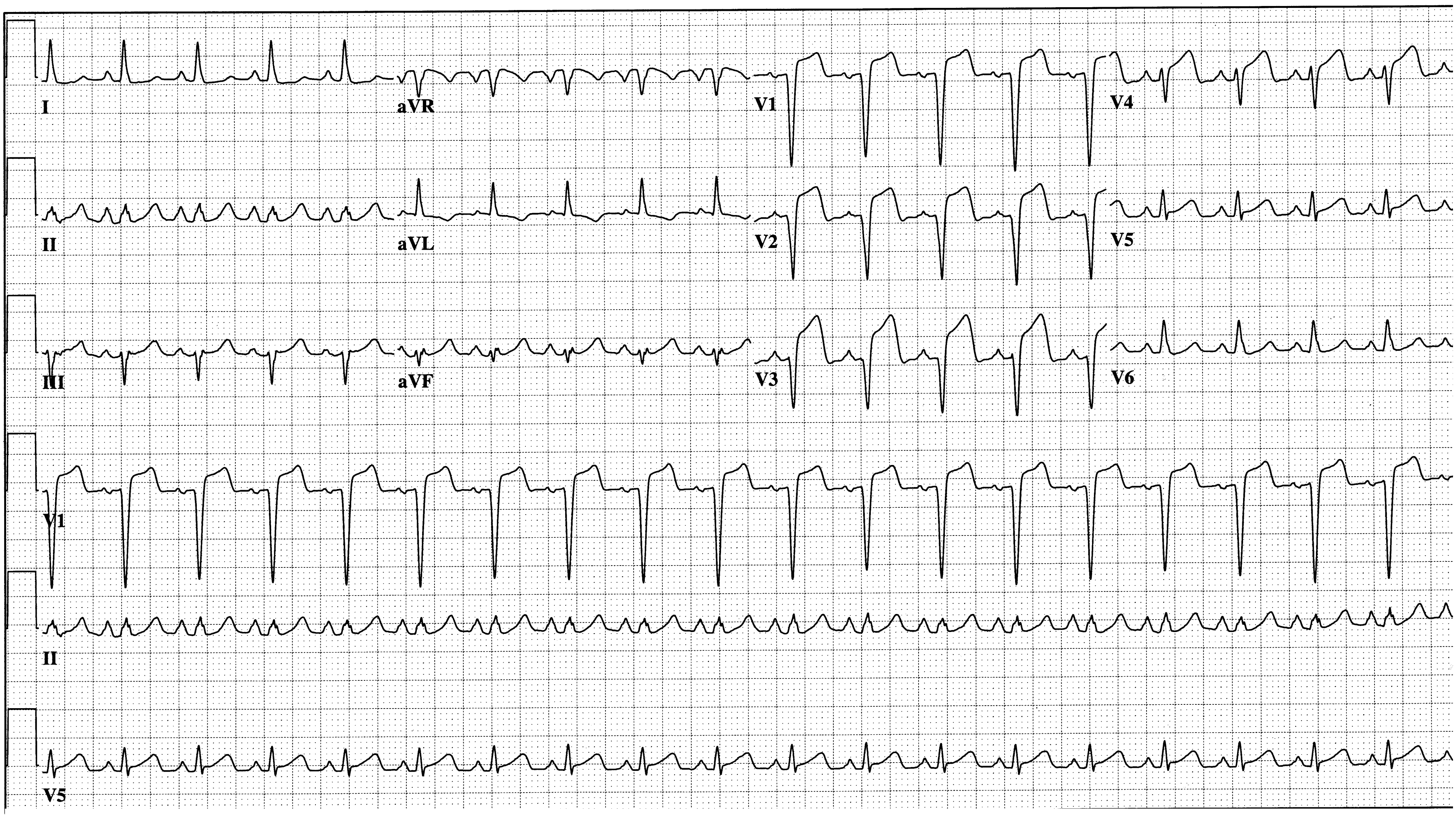
Atrial rate: ______________________ QRS complex: ST segment: ______________________

Ventricular rate: ______________________ Axis: ______________________ T wave: ______________________

Rhythm: ______________________ Duration: ______________________ QT interval: ______________________

P wave: ______________________ Voltage: ______________________ U wave: ______________________

PR interval: ______________________ Morphology: ______________________ Diagnosis: ______________________



ECG 19

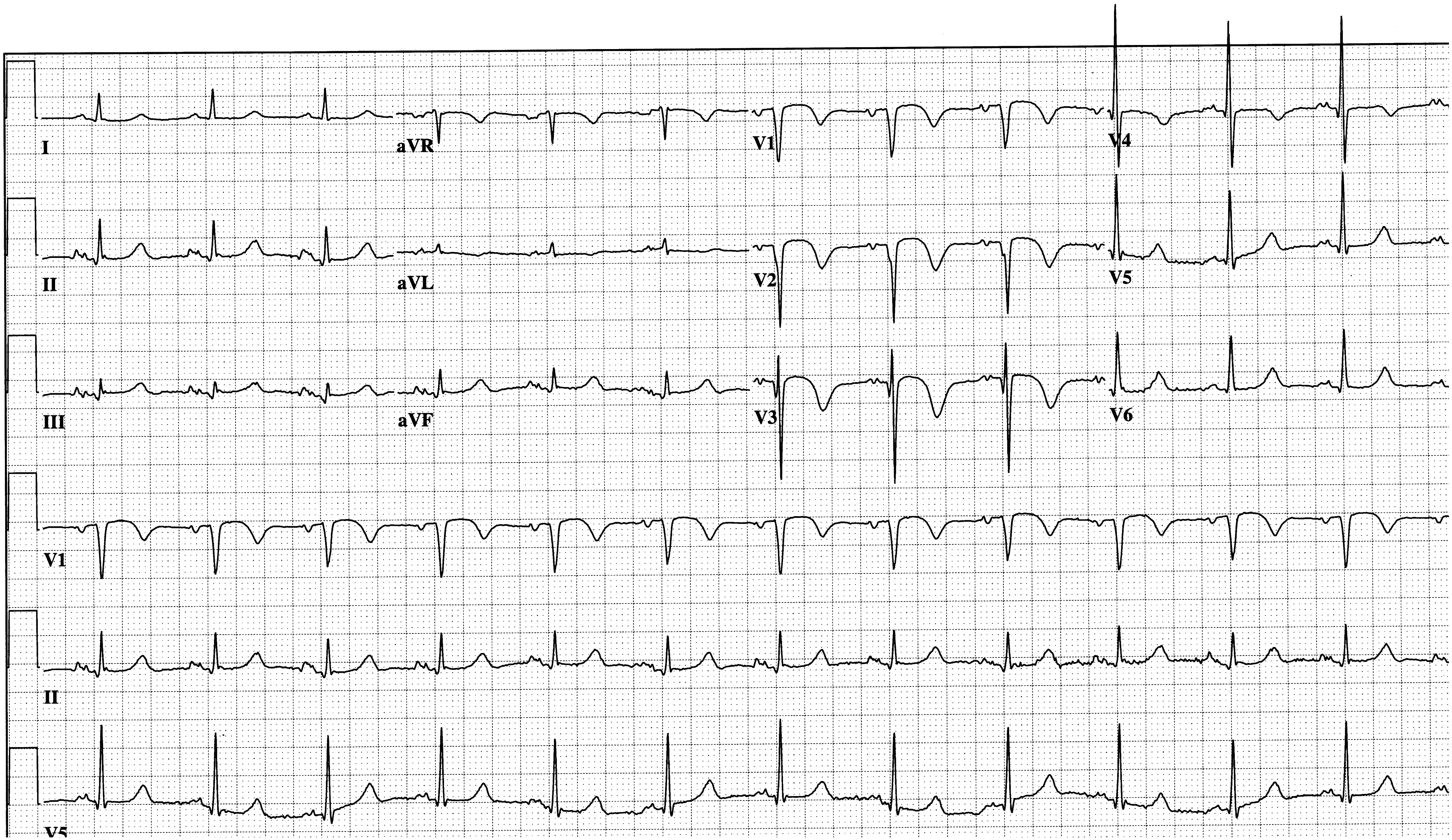
Atrial rate: ______________________ QRS complex: ST segment: ______________________

Ventricular rate: ______________________ Axis: ______________________ T wave: ______________________

Rhythm: ______________________ Duration: ______________________ QT interval: ______________________

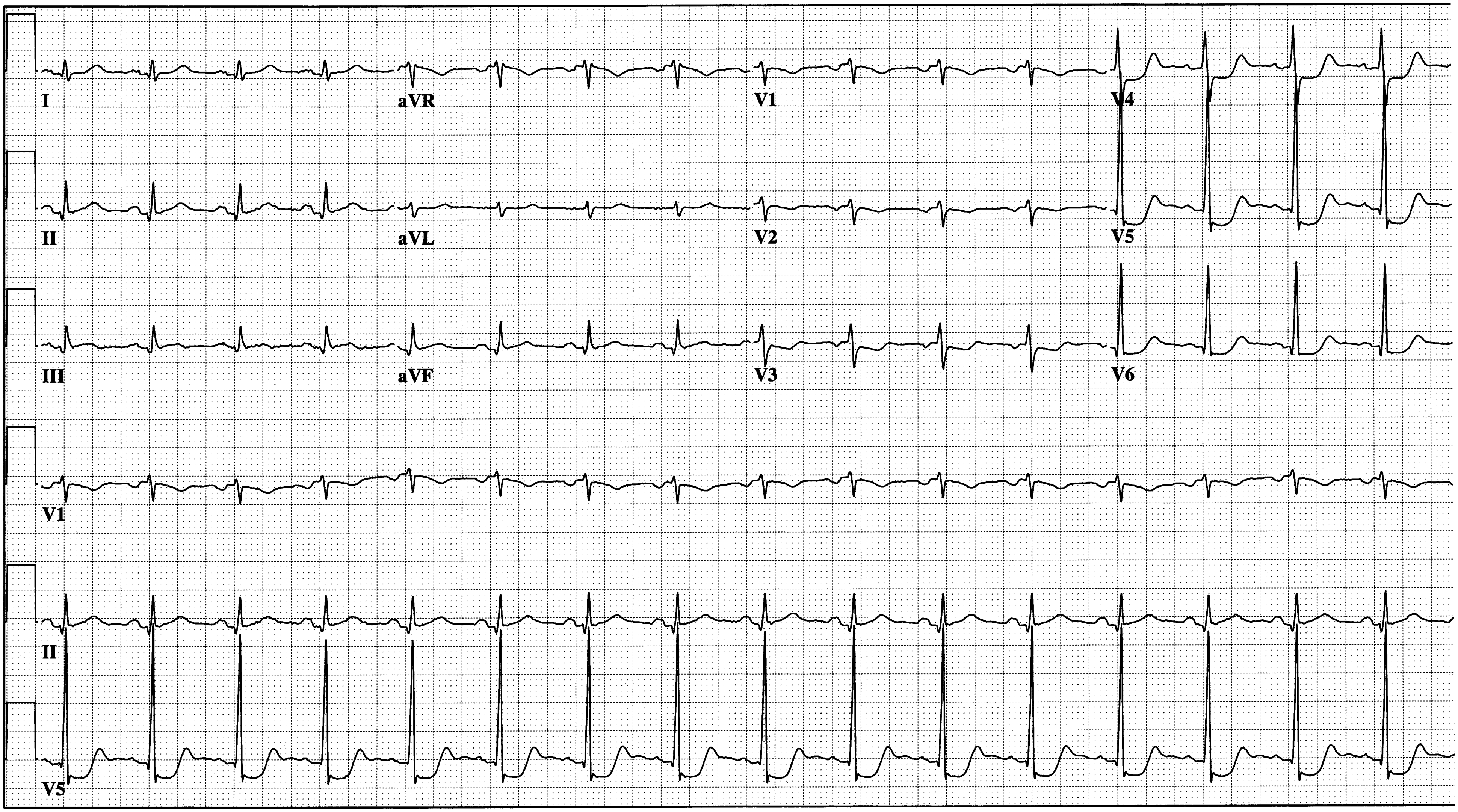
P wave: ______________________ Voltage: ______________________ U wave: ______________________

PR interval: ______________________ Morphology: ______________________ Diagnosis: ______________________



ECG 20

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



Ischemia and Infarction

Interpretations of Sample Tracings
ECG 1

Atrial rate:
Ventricular rate: 150
Rhythm: Atrial fibrillation with rapid ventricular response
P wave:
PR interval:
QRS complex:
  Axis: −75°
  Duration: 110 msec
  Voltage: Normal
  Morphology: Q waves in V_1 and V_2
ST segment: Diffuse ST segment depression, and elevation in V_1 and V_2
T wave: Normal
QT interval: 310 msec
U wave:
Diagnosis: Atrial fibrillation with rapid ventricular response, left axis deviation, and diffuse ST changes consistent with ischemia and possible acute septal MI

ECG 2

Atrial rate: 54
Ventricular rate: 54
Rhythm: Sinus bradycardia
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: 110°
  Duration: 180 msec, RBBB
  Voltage: Normal
  Morphology: Q waves in V_1 to V_3
ST segment: Normal
T wave: Normal
QT interval: 480 msec
U wave:
Diagnosis: Sinus bradycardia with right axis deviation, RBBB, and old anteroseptal MI. It is essential that one recognize the presence of concomitant RBBB and the infarct. The expected R wave of the RSRí in V_1 has been replaced by a Q wave.

ECG 3
Atrial rate: 68
Ventricular rate: 68
Rhythm: Sinus rhythm

P wave: Normal
PR interval: 180 msec
QRS complex:
  Axis: −75°
  Duration: 110 msec, with an incomplete RBBB
  Voltage: Normal
  Morphology: Q wave in V_1 to V_4, III and aVF
ST segment: Elevated in V_1 to V_5
T wave: Normal
QT interval: 380 msec
U wave:
Diagnosis: Sinus rhythm with left axis deviation, incomplete RBBB (the morphology of RBBB is present but the QRS deviation is <120 msec), old inferior MI, and anterior MI, probably recent. Once again, the R wave of the RSR' in V_1 of the incomplete RBBB has been replaced by a Q wave.

ECG 4

Atrial rate: 86
Ventricular rate: 86
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 140 msec
QRS complex:
  Axis: 80°
  Duration: 115 msec, with an incomplete RBBB
  Voltage: Normal
  Morphology: Normal
ST segment: Hyperacute ST segment elevation in II, III, and aVF with depression in aVL
T wave: Normal
QT interval: 380 msec
U wave:
Diagnosis: Sinus rhythm with an incomplete RBBB and ST segment elevation consistent with an inferior MI. The lack of any significant Q waves in the inferior leads means that this infarct is very recent in onset.

ECG 5

Atrial rate: 43
Ventricular rate: 43
Rhythm: Sinus bradycardia
P wave: Normal
PR interval: 180 msec
QRS complex:
  Axis: Right superior axis deviation
  Duration: 80 msec

Voltage: Low voltage
Morphology: Q waves in II, III and aVF, and V_2 to V_5
ST segment: ST segment elevation in V_2 to V_5
T wave: Inverted in I, aVL, and V_2 to V_6
QT interval: 480 msec
U wave:
Diagnosis: Sinus bradycardia with right superior axis deviation, low voltage, old inferior MI, and an anterior MI, age undetermined. In this case, the anterior MI was present on an ECG from three months previously, suggesting that the residual ST segment elevation may indicate the presence of an LV aneurysm.

ECG 6

Atrial rate: 64
Ventricular rate: 64
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 200 msec
QRS complex:
Axis: 60°
Duration: 180 msec, RBBB
Voltage: Normal
Morphology: Q waves in V_1 to V_5, I, and aVL</unl2>
ST segment: Normal
T wave:
QT interval: 430 msec
U wave:
Diagnosis: Sinus rhythm with RBBB, and an old anterolateral MI

ECG 7

Atrial rate: 62
Ventricular rate: 62
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 180 msec
QRS complex:
Axis: –75°
Duration: 105 msec
Voltage: Normal
Morphology: Q waves in II, III, and aVF, and tall R waves in V_1 and V_2
ST segment: Normal
T wave: Normal
QT interval: 410 msec
U wave:
Diagnosis: Sinus rhythm with left axis deviation and an old inferoposterior MI

ECG 8

Atrial rate: 75
Ventricular rate: 75
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: −10°
  Duration: 85 msec
  Voltage: Normal
  Morphology: Q waves in II, III, and aVF, I and V_4 to V_6, prominent R wave in V_2
ST segment: Normal
T wave: Normal
QT interval: 390 msec
U wave:
Diagnosis: Sinus rhythm with an old inferolateral and posterior MI

ECG 9

Atrial rate: 77
Ventricular rate: 77
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 300 msec
QRS complex:
  Axis: −75°
  Duration: 160 msec, RBBB
  Voltage: Normal
  Morphology: Q waves in II, III, and aVF
ST segment: Normal
T wave: Inverted in II, III, and aVF
QT interval: 430 msec
U wave:
Diagnosis: Sinus rhythm with a long first degree AV block, left axis deviation, RBBB, and an old inferior MI

ECG 10

Atrial rate: 43
Ventricular rate: 43
Rhythm: Sinus bradycardia
P wave: Normal
PR interval: 140 msec

QRS complex:
 Axis: 90°
 Duration: 105 msec, with incomplete RBBB
 Voltage: Normal
 Morphology: Normal
ST segment: Hyperacute ST segment elevation in II, III, and aVF, with depression in I, aVL, and V_2 to V_6
T wave: Normal
QT interval: 500 msec
U wave:
Diagnosis: Sinus bradycardia with an incomplete RBBB, and an acute inferior MI

ECG 11

Atrial rate: 93
Ventricular rate: 93
Rhythm: sinus rhythm
P wave: Normal
PR interval: 140 msec
QRS complex:
 Axis: 45°
 Duration: 80 msec
 Voltage: Normal
 Morphology: Small Q waves in II, III, and aVF
ST segment: Normal
T wave: Normal
QT interval: 340 msec
U wave:
Diagnosis: Sinus rhythm with small Q waves in II, III, and aVF. The Q waves are perhaps 40 msec in duration, but they are not one-quarter the height of R waves (at least in II).

ECG 12

Atrial rate:
Ventricular rate: 114
Rhythm: Atrial fibrillation with a rapid ventricular response
P wave:
PR interval:
QRS complex:
 Axis: 145°
 Duration: 140 msec, RBBB, left posterior fascicular block (LPFB)
 Voltage: Normal
 Morphology: Normal
 ST segment: ST elevation in III with diffuse ST segment depression
 T wave:

QT interval: 380 msec
U wave:
Diagnosis: Sinus rhythm with a right axis deviation, RBBB, left posterior fascicular block, inferior ST segment elevation and widespread depression consistent with an acute inferior MI

ECG 13

Atrial rate: 83
Ventricular rate: 83
Rhythm: Sinus rhythm with first degree AV block
P wave: Normal
PR interval: 280 msec
QRS complex:
Axis: 120°
Duration: 140 msec, RBBB, LPFB
Voltage: Normal
Morphology: Q waves in III and aVF
ST segment: Elevated in III and aVF with depression in I and aVL
T wave:
QT interval: 360 msec
U wave:
Diagnosis: Sinus rhythm with first degree AV block, right axis deviation, RBBB, left posterior fascicular block, and ST segment elevation in III and aVF consistent with an acute inferior MI

ECG 14

Atrial rate: 110
Ventricular rate: 55
Rhythm: Sinus tachycardia with second degree AV block, probably type I
P wave: Normal
PR interval:
QRS complex:
Axis: 45°
Duration: 90 msec
Voltage: Normal
Morphology: Q waves in V_1 and V_2
ST segment: ST elevation in II, III, and V_3 to V_6
T wave: Inverted in aVL
QT interval: 550 msec
U wave:
Diagnosis: Sinus tachycardia with second degree AV block, old septal MI, an acute inferolateral MI. The second P wave is best seen in V_1 and V_2. Significant AV block is common in an acute inferior MI

ECG 15

Atrial rate: 43
Ventricular rate: 43
Rhythm: Sinus bradycardia
P wave: Normal
PR interval: 140 msec
QRS complex:
  Axis: 90°
  Duration: 115 msec, with an incomplete RBBB
  Voltage: Normal
  Morphology: Normal
ST segment: Hyperacute ST elevation in II, III, and aVF, with depression in aVL, V_2, and V_3
T wave: Normal
QT interval: 500 msec
U wave:
Diagnosis: Sinus bradycardia with incomplete RBBB and an acute inferior MI

ECG 16

Atrial rate: 70
Ventricular rate: 70
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 210 msec
QRS complex:
  Axis: −45°
  Duration: 110 msec
  Voltage: Normal
  Morphology: Q waves in II, III, and aVF, tall R waves in V_1 and V_2, and low voltage in V_4 to V_6
ST segment: Normal
T wave: Normal
QT interval: 400 msec
U wave:
Diagnosis: Sinus rhythm with a previous inferoposterior MI. The small R waves in V_4 to V_6 may indicate involvement of the lateral wall.

ECG 17

Atrial rate: 53
Ventricular rate: 53
Rhythm: Sinus bradycardia
P wave: Normal

PR interval: 160 msec
QRS complex:
  Axis: −30°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Q waves in II, III, and aVF, and a tall R wave in V_2
ST segment: Normal
T wave: Peaked in V_2 and V_3
QT interval: 440 msec
U wave:
Diagnosis: Sinus bradycardia with an old inferoposterior MI

ECG 18

Atrial rate: 115
Ventricular rate: 115
Rhythm: Sinus tachycardia
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: 0°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Q waves in V_1 to V_3
ST segment: ST elevation in V_1 to V_5
T wave: Normal
QT interval: 320 msec
U wave:
Diagnosis: Sinus tachycardia with an acute anterior MI

ECG 19

Atrial rate: 75
Ventricular rate: 75
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 140 msec
QRS complex:
  Axis: 45°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Q waves in V_1 to V_3
ST segment: Slight elevation in V_1 to V_3
T wave: Deeply inverted in V_1 to V_4
QT interval: 440 msec

U wave:
Diagnosis: Sinus rhythm with and anteroseptal MI of undetermined age. The deep T wave inversion suggests, but does not confirm, that the event was recent.

ECG 20

Atrial rate: 95
Ventricular rate: 95
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 140 msec
QRS complex:
  Axis: 75°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Depression in V_2 to V_6
T wave: Normal
QT interval: 340 msec
U wave:
Diagnosis: Sinus rhythm with diffuse ST segment depression consistent with ischemia

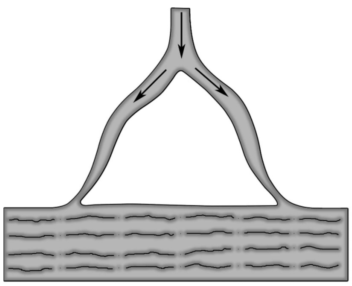
Day 5

Reentrant Arrhythmias

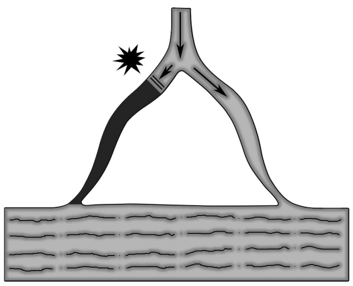
I. Reentry—a disorder of impulse transmission

A. Mechanisms of reentry

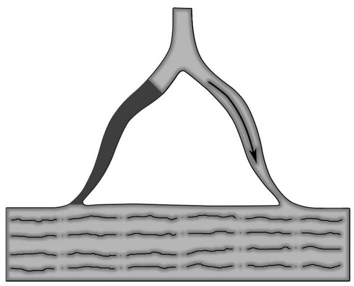
1. Reentry requires:
    a. At least two conduction pathways
    b. Variable block in one of the pathways
2. If two pathways have similar conduction velocities, the electrical impulses will merge distally and no arrhythmia will occur (see figure).
3. If an event (e.g., a premature ventricular contraction [PVC]) occurs at the right time and place to make one of the two pathways refractory, the impulse will be blocked in that limb.



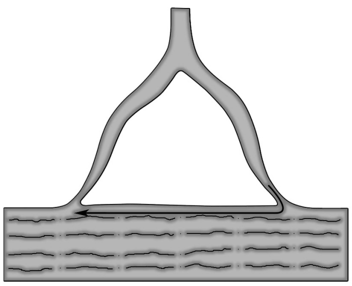
Normal conduction down a terminal branch of a Purkinje fiber, which depolarizes ventricular myocardium in an orderly sequence.



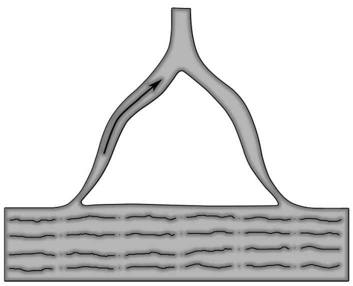
In the situation above, a fortuitously timed PVC depolarizes one limb of the fiber, blocking conduction. The other limb depolarizes normally.



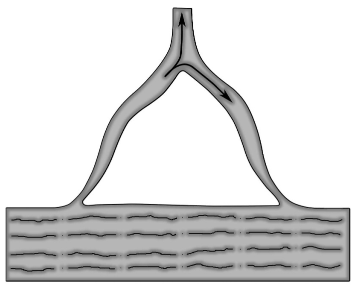
The depolarization continues down one limb while the other repolarizes.



The ventricular myocardium depolarizes, which registers as a PVC on the ECG. In the meantime, repolarization is complete in the other limb.



The impulse is free to travel retrograde up the now fully repolarized limb.



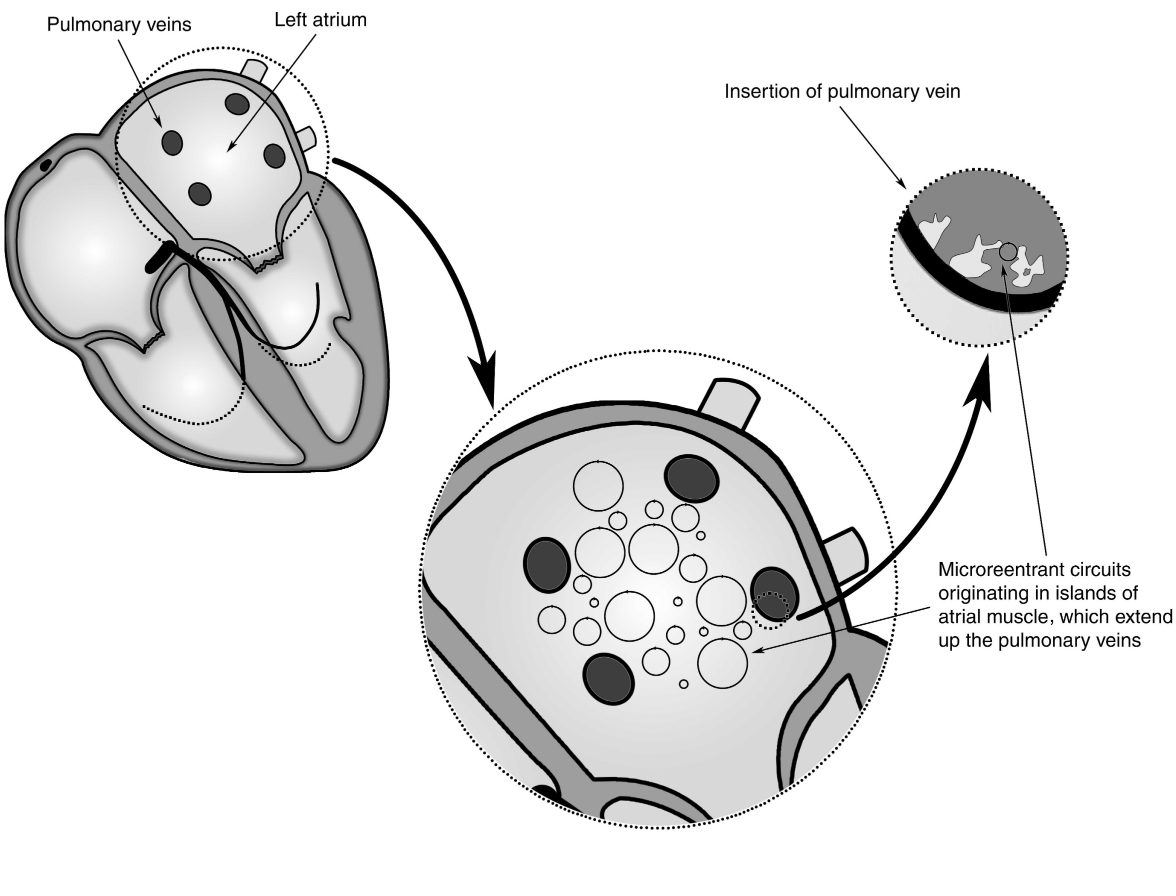
If the impulse arrives at the branch point before the next normal depolarization arrives from above, the reentry loop may sustain itself, resulting in ventricular tachycardia.

4. If the impulse from the other limb travels back up the blocked limb, it may find the previously refractory area able to conduct.
5. If the impulse reaches the initial branch point of the two pathways before the next normal impulse arrives from above, the arrhythmia can perpetuate itself.

B. Properties of reentrant arrhythmias
1. Reentrant arrhythmias start and stop abruptly (paroxysmally).
2. They are usually initiated by a premature beat.
3. The reentrant arrhythmias that have a discreet reentrant pathway [atrial flutter, AV nodal reentrant tachycardia [AVNRT], most ventricular tachycardia (VT)] are very regular.
4. Reentrant arrhythmias can be terminated by any mechanism, which makes some part of the reentrant pathway refractory, including vagal maneuvers (AVNRT), chest thump (VT), medications which slow conduction (most reentrant arrhythmias) or electrocardioversion (all reentrant arrhythmias).

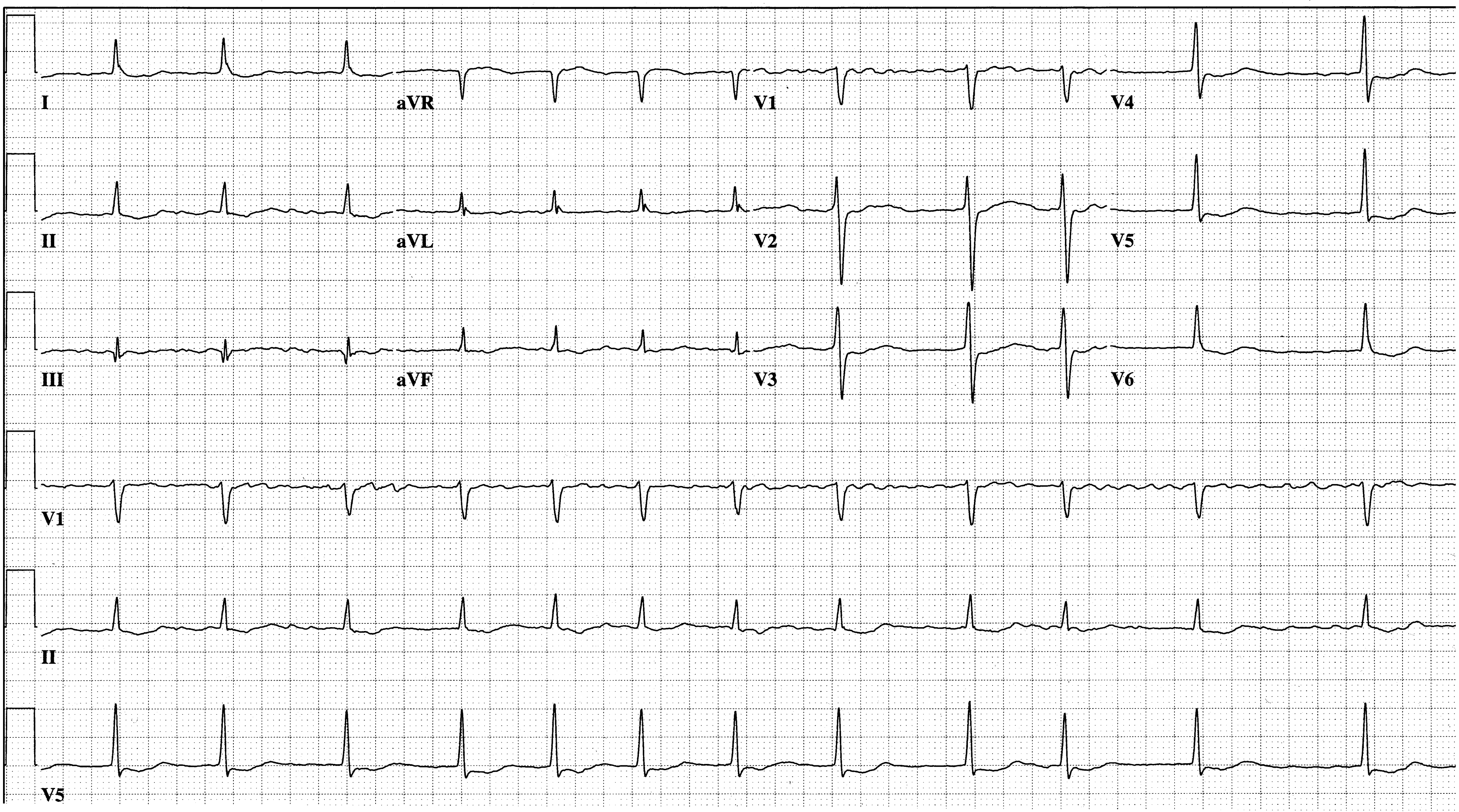
II. The major reentrant arrhythmias

A. Atrial fibrillation
1. Mechanisms and causes (Day 5-01) (Day 5-02) (Day 5-03) (Day 5-04)



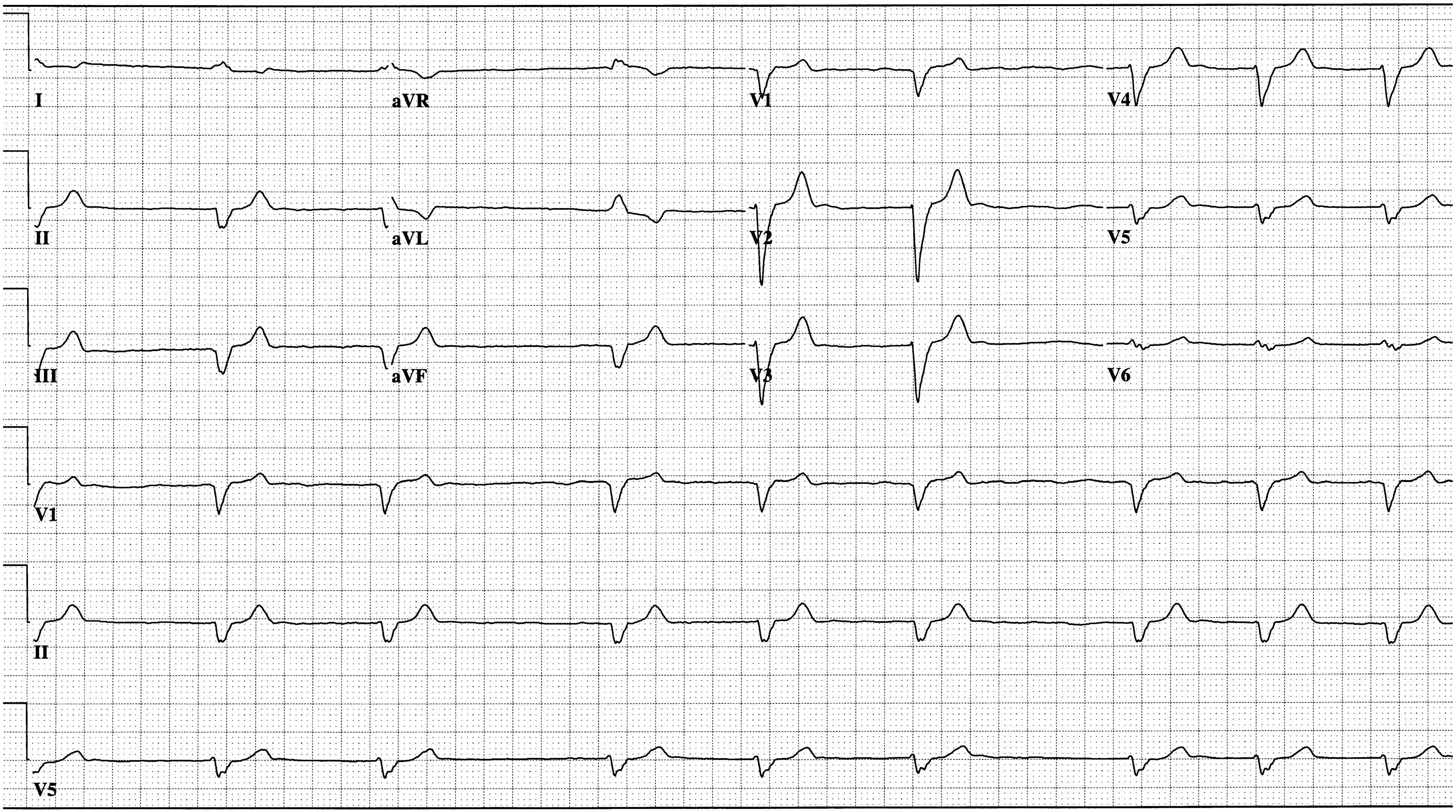
DAY 5-01

Atrial fibrillation as indicated by an irregular baseline and irregular ventricular response



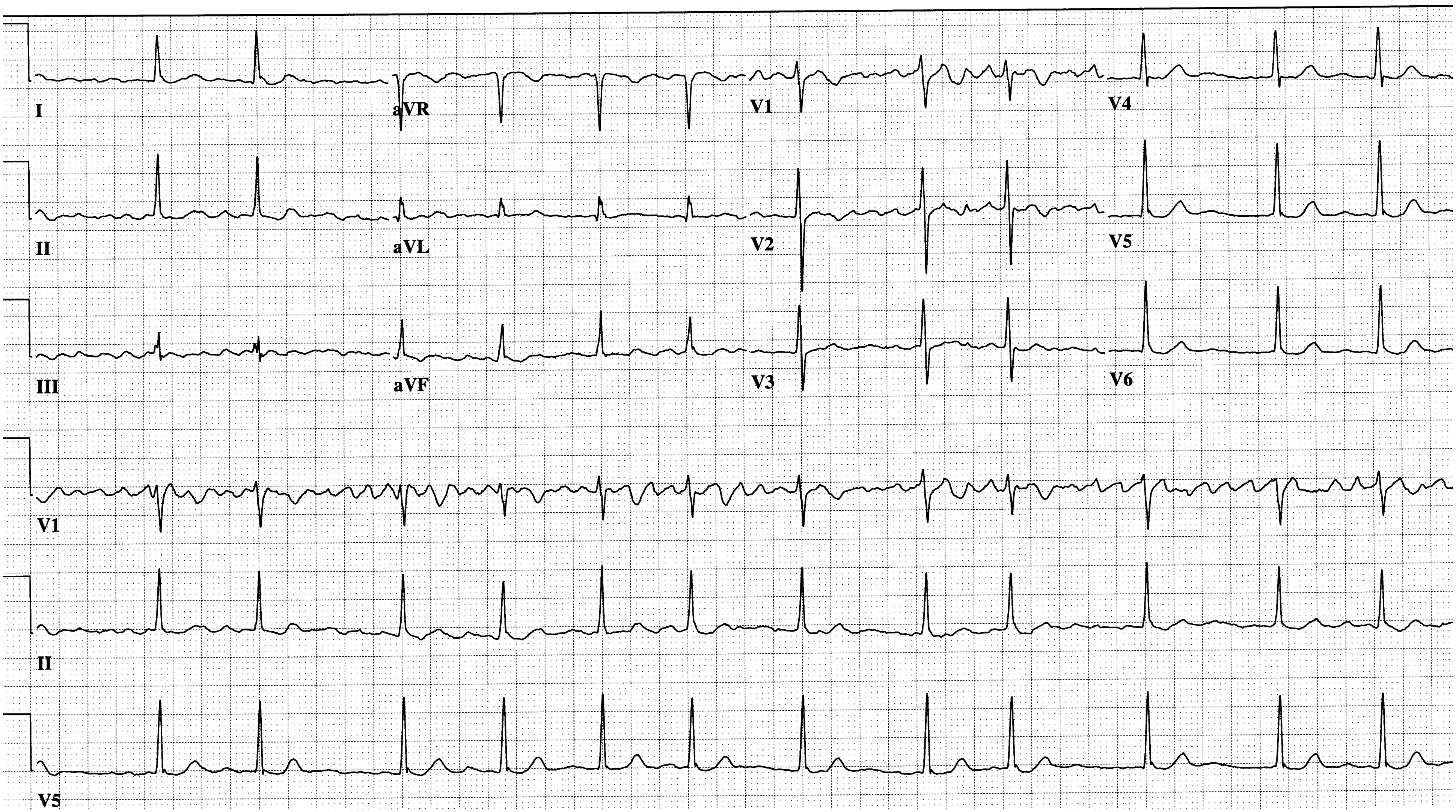
DAY 5-02

Atrial fibrillation with an irregular ventricular response but little variation in the baseline



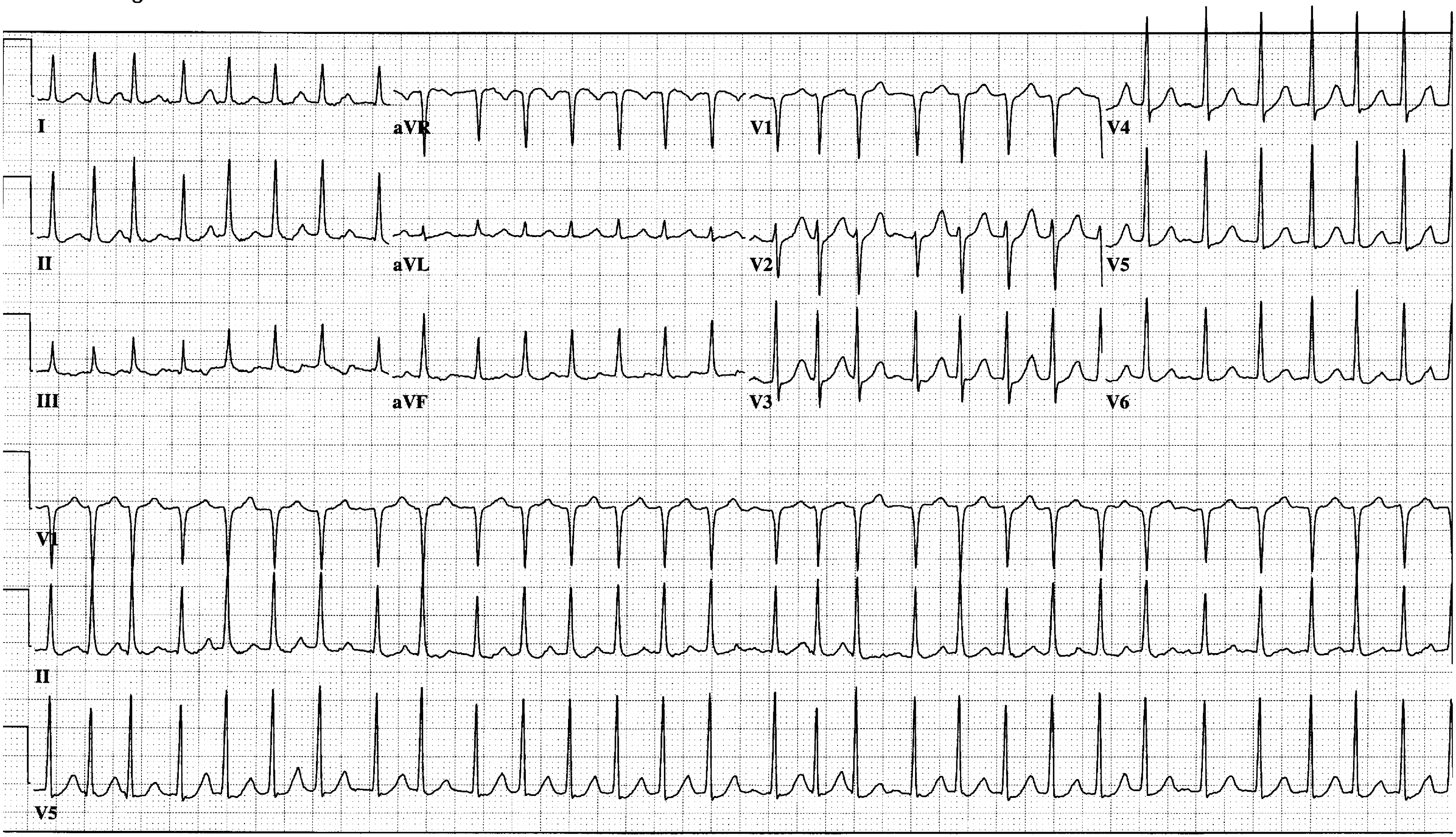
DAY 5-03

Atrial fibrillation with a coarse (but irregular) baseline and irregular ventricular response



DAY 5-04

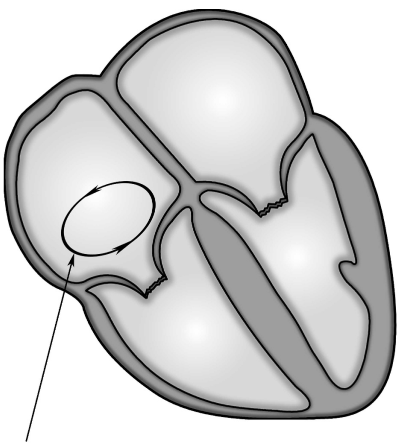
Atrial fibrillation with rapid ventricular response. There is less irregularity in the ventricular rate and the irregular baseline is difficult to discern.



a. The most likely cause of atrial fibrillation is microreentry between islands of atrial muscle in the vicinity of the insertion of the pulmonary veins into the left atrium.
b. Atrial fibrillation requires a certain amount of atrial tissue to be present to sustain the arrhythmia (an important concept in therapeutic approaches).
c. Atrial pressure overload (e.g., from heart failure, hypertensive heart disease, ventricular failure, or valvular heart disease) is the clinical situation responsible for the vast majority of cases.

2. Heart rate
   a. The multiple reentrant wave fronts combine to have an atrial rate of 400–600.
   b. The ventricular response is irregular.
3. ECG morphology
   a. The baseline varies from coarse, irregular fibrillatory waves to virtually flat.
   b. The QRS complexes are narrow unless there is an intraventricular conduction defect (IVCD).
4. Response to vagal maneuvers or AV nodal blocking medications (i.e., IV adenosine).
   a. These maneuvers do not affect the atrial fibrillation itself.
   b. The ventricular response is irregularly slowed.

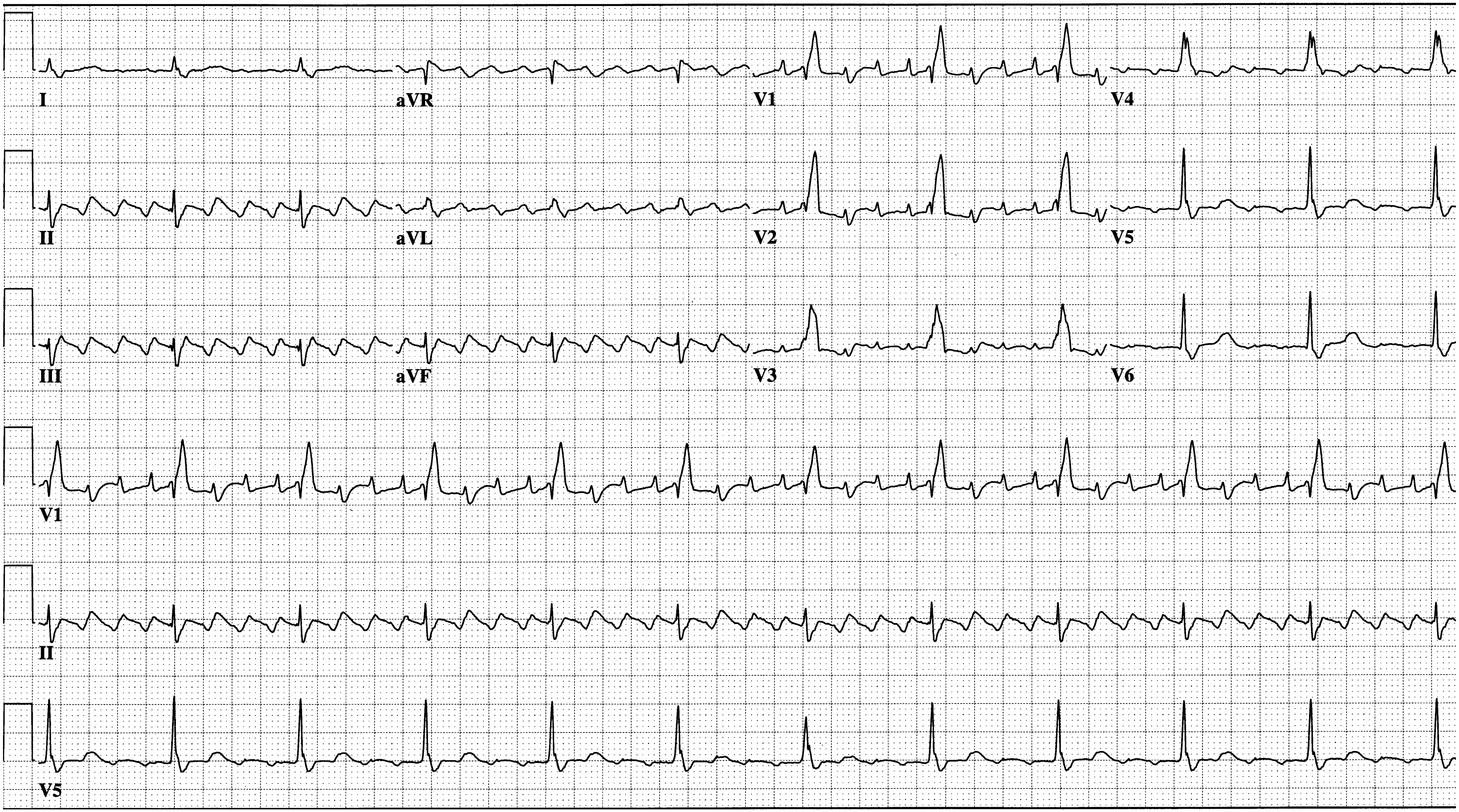
B. Atrial flutter
1. Mechanisms and causes (Day 5-05) (Day 5-06)
   a. Most examples are likely due to reentry.
   b. The common reentry pathway is counterclockwise around the tricuspid annulus and involving the interatrial septum.
   c. Atypical forms exist, which presumably have other reentrant pathways and are often faster than typical flutter. (Day 5-07)
   d. Atrial pressure overload (from similar causes as for atrial fibrillation) is responsible for the majority of cases.



Typical counterclockwise reentrant loop around the tricuspid annulus of atrial flutter

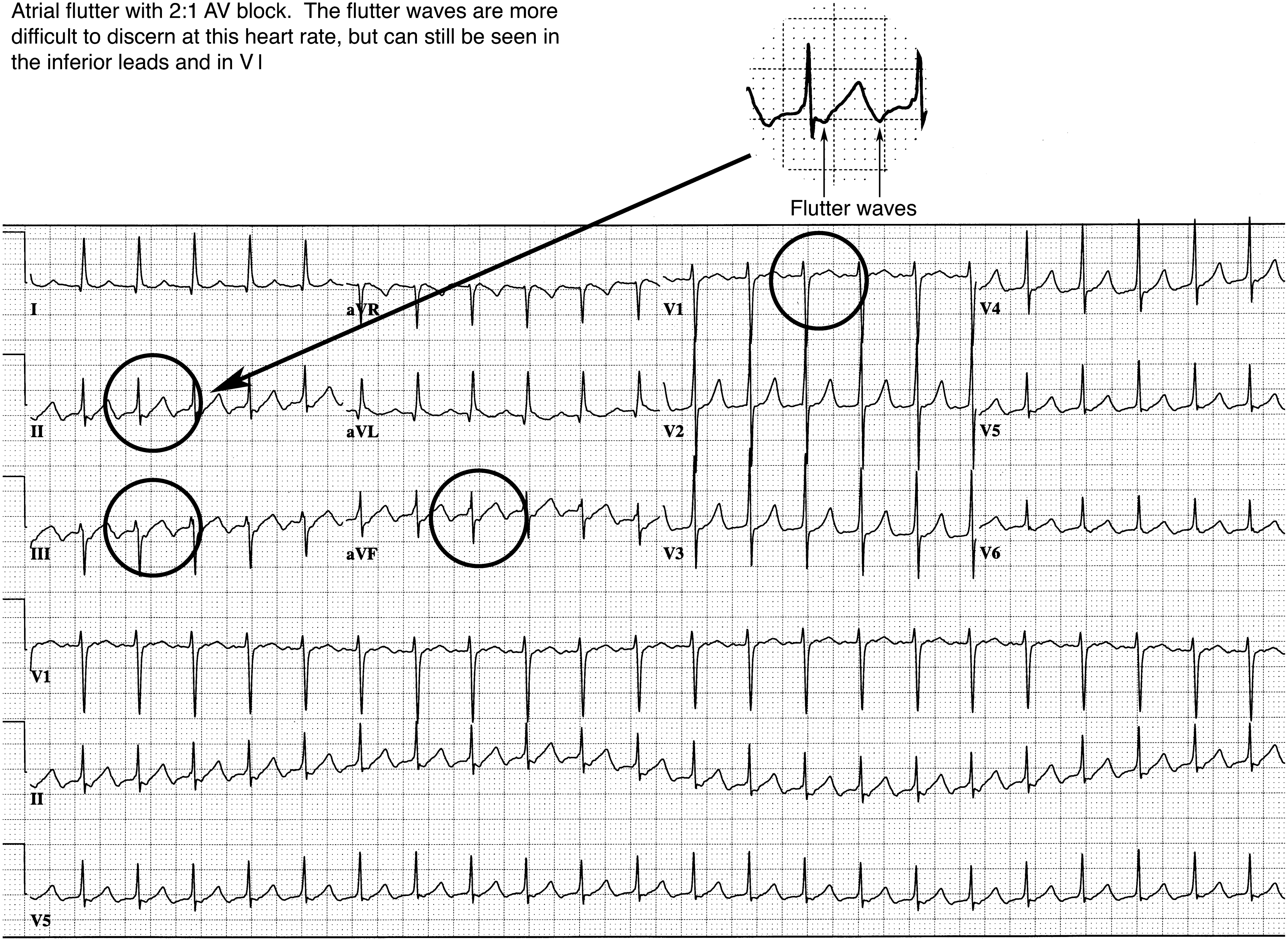
DAY 5-05

Atrial flutter with 4:1 AV conduction



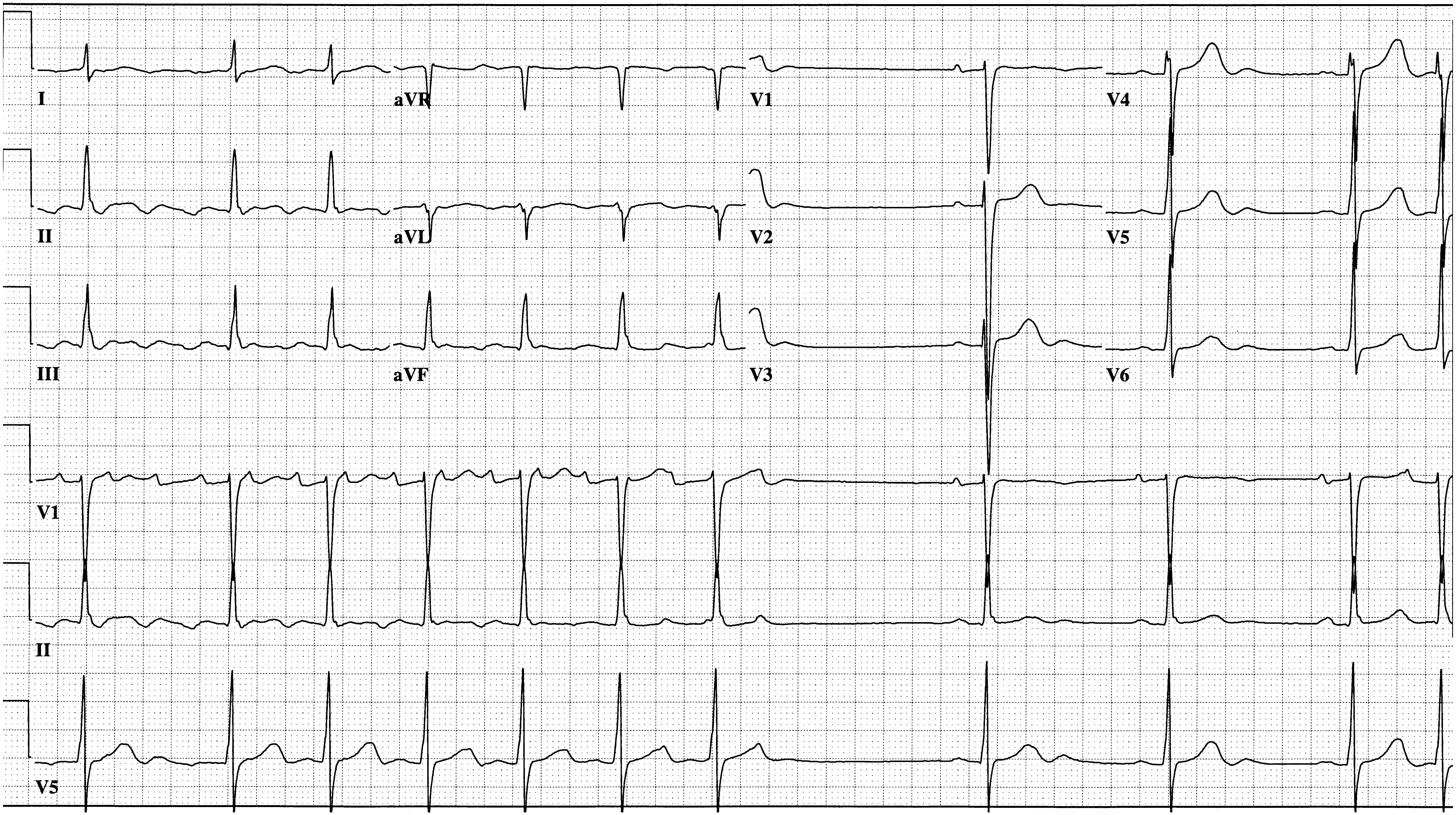
DAY 5-06

Atrial flutter with 2:1 AV block. The flutter waves are more difficult to discern at this heart rate, but can still be seen in the inferior leads and in V1



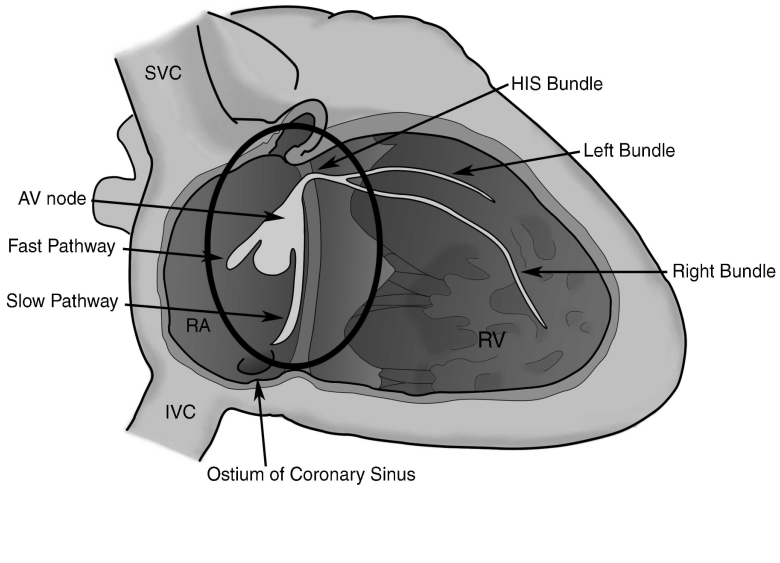
DAY 5-07

Atrial flutter with variable AV block converting paroxysmally to sinus rhythm, demonstrating the reentrant nature of this arrhythmia



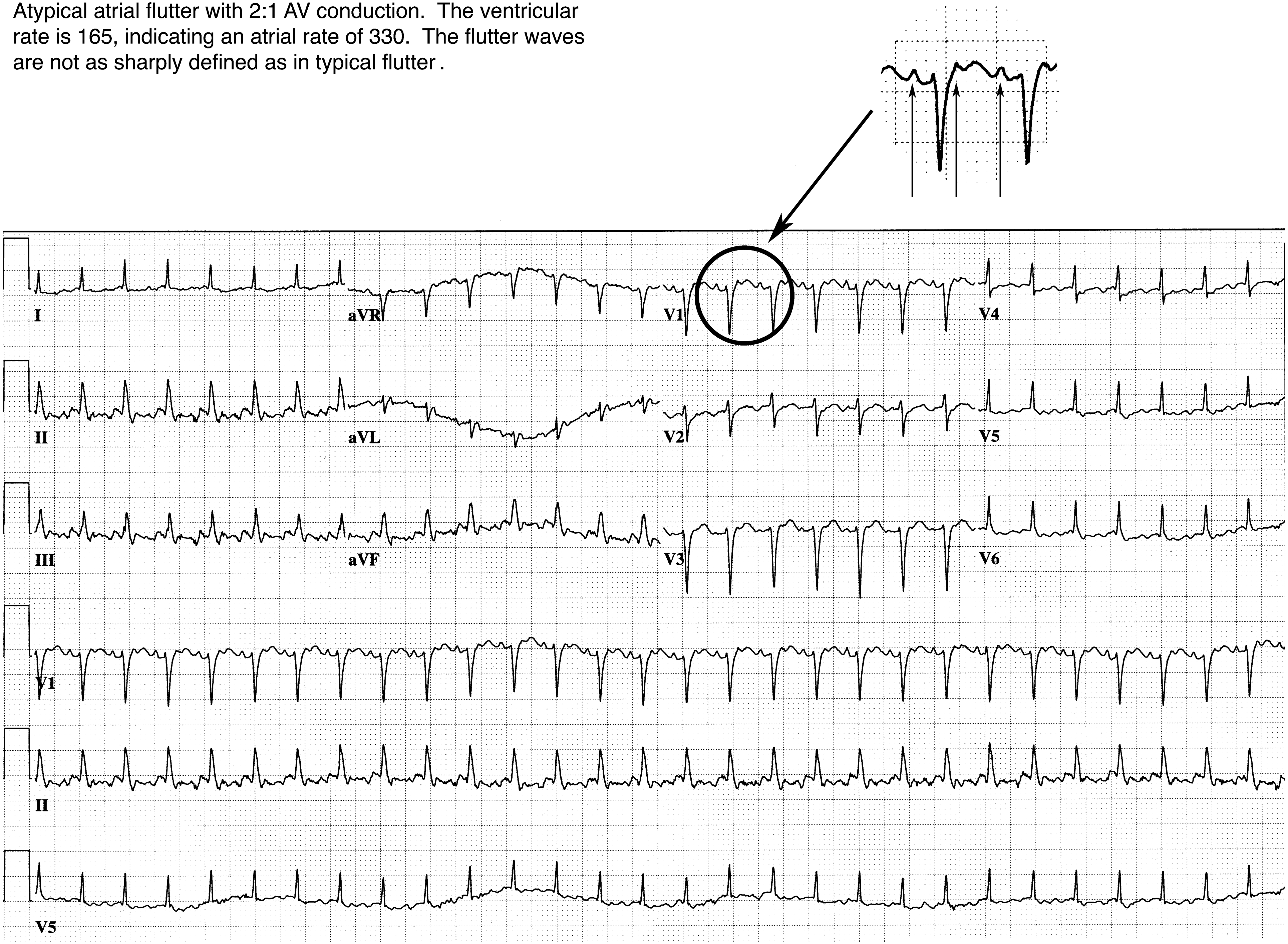
2. Heart rate
   a. The atrial rate is 220–320, more commonly 280–320, with a median of 300.
   b. Patients receiving antiarrhythmic therapy (e.g., with quinidine, sotalol, or amiodarone) may have slower (as low as 200) flutter rates.
   c. The ventricular response is usually a whole even number division of the atrial rate (2:1, 4:1, 8:1), although alternating 2:1/4:1 or variable ventricular responses are encountered. (Day 5-08) (Day 5-09)
   d. One of Marriott's laws—every absolutely regular supraventricular tachycardia with a rate of 150 is atrial flutter with 2:1 block until proven otherwise.
   e. Rarely, atrial flutter can present with 1:1 AV conduction. (Day 5-10)
3. ECG morphology
   a. The baseline in typical flutter usually demonstrates extremely regular sawtooth flutter waves in Leads II, III, aVF, or V_1, although the flutter waves may be difficult to discern if the ventricular rate is rapid.
   b. The QRS complexes are narrow unless there is an IVCD.
4. Response to vagal maneuvers or AV nodal blocking medications
   a. Vagal maneuvers do not affect the atrial flutter itself.
   b. The ventricular response is slowed, usually in whole number divisions of the atrial rate, unmasking the underlying flutter waves.

C. AV nodal reentrant tachycardia (AVNRT)
1. Mechanisms
   a. Anatomy of the AV node.
   b. The electrical properties of the AV node with its fast and slow pathways with different repolarization rates, facilitate reentry.



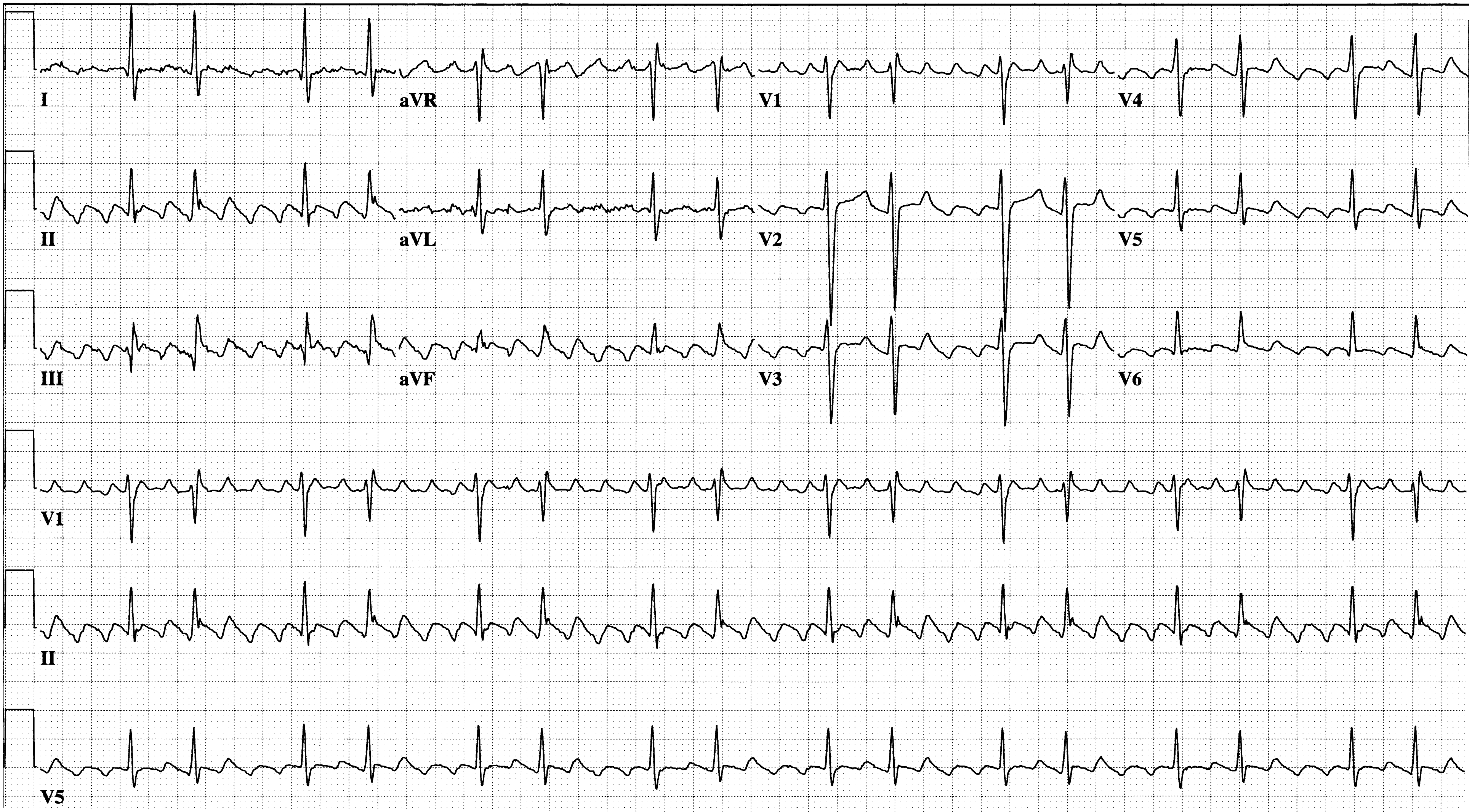
DAY 5-08

Atypical atrial flutter with 2:1 AV conduction. The ventricular rate is 165, indicating an atrial rate of 330. The flutter waves are not as sharply defined as in typical flutter.



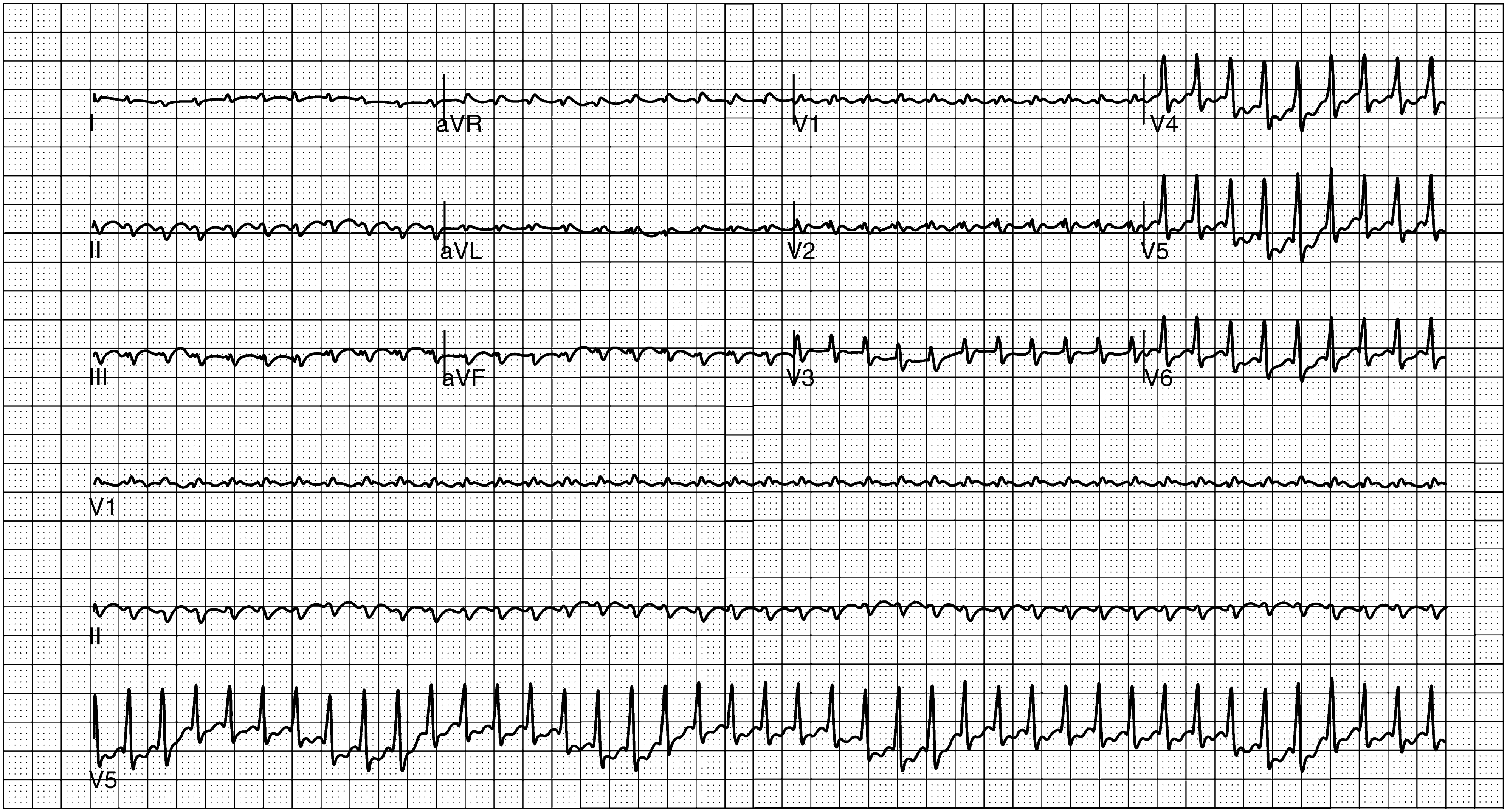
DAY 5-09

Atrial flutter with variable AV block

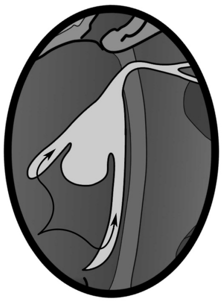


DAY 5-10

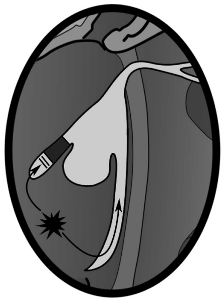
Atrial flutter with 1:1 AV conduction. Subsequent administration of IV adenosine verified this diagnosis; otherwise this arrhythmia would be impossible to distinguish from other supraventricular tachycardias at this rate.



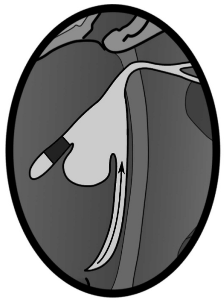
c. "Short R-P" form
   (1) In about 90% of patients with AVNRT, the fast pathway has a longer refractory period (i.e., takes longer to repolarize) than the slow pathway.
   (2) A fortuitously timed premature atrial complex (PAC) may be conducted down the slow pathway while the fast pathway is still refractory, thus setting the stage for a reentrant arrhythmia.



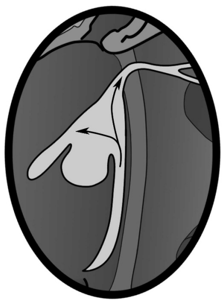
Normal conduction through the AV node



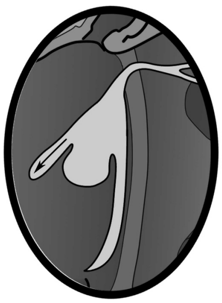
In the situation above, a fortuitously timed PAC is conducted down the slow pathway. The fast pathway, which has a longer repolarization time, is still refractory.



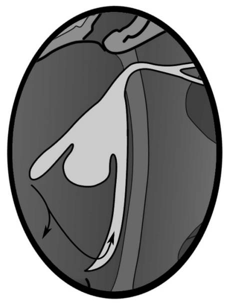
The conduction continues down the slow pathway while the fast pathway completes its repolarization



The impulse is free to travel down the His bundle and depolarize the ventricles. Meanwhile, the fast pathway has repolarized.



The impulse is free to travel retrograde up the fast pathway



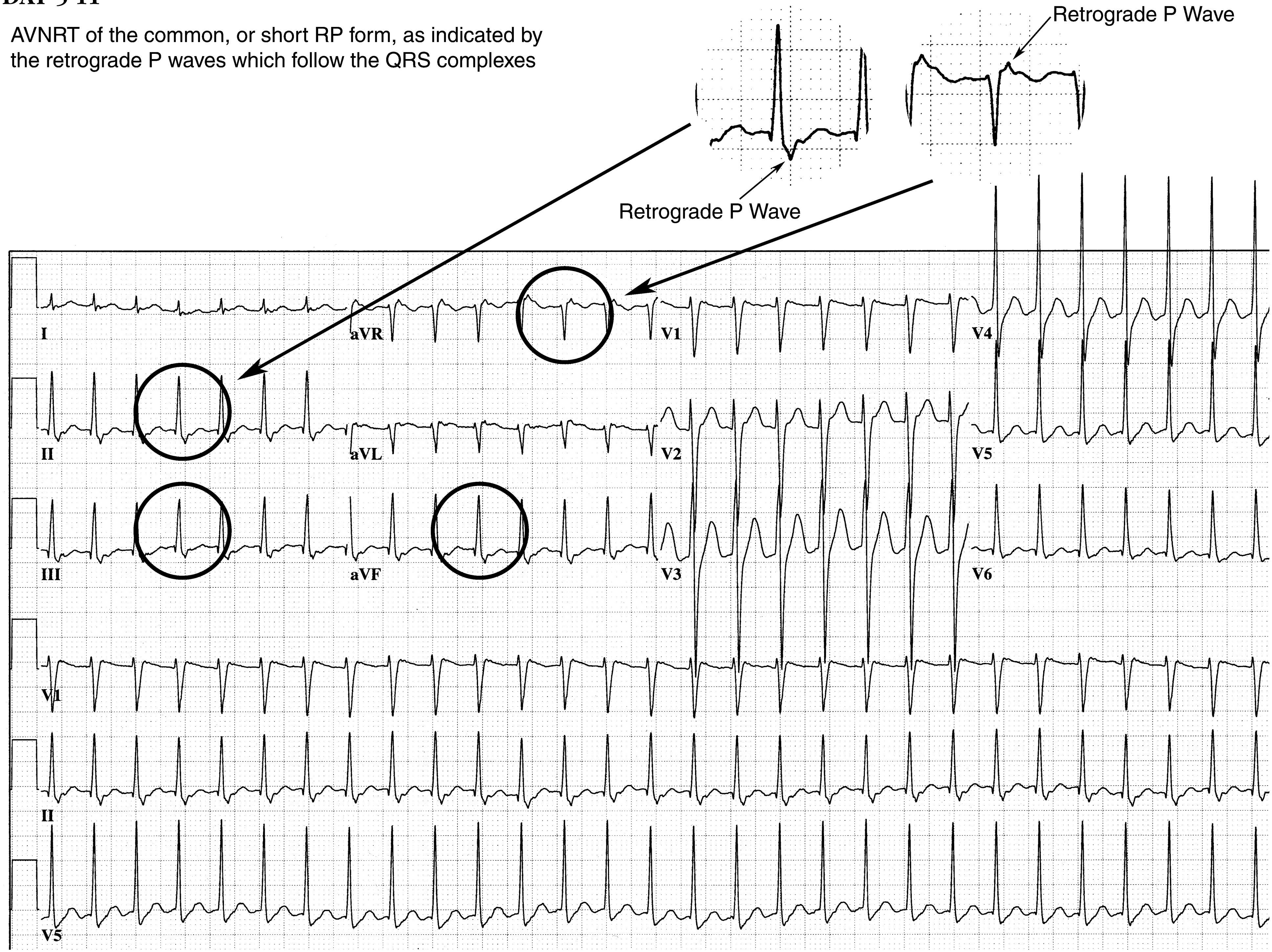
If the impulse arrives at the branch point before the next normal depolarization arrives from above, the reentry loop may sustain itself, resulting in AVNRT

   (3) Since the impulse travels down the slow pathway and back up the fast pathway, there is a retrograde P wave buried within the QRS complex or shortly thereafter. (Day 5-11) (Day 5-12)

d. "Long R-P" form
   (1) In about 10% of patients, the slow pathway appears to have a longer refractory period (i.e., repolarizes more slowly) than the fast pathway.

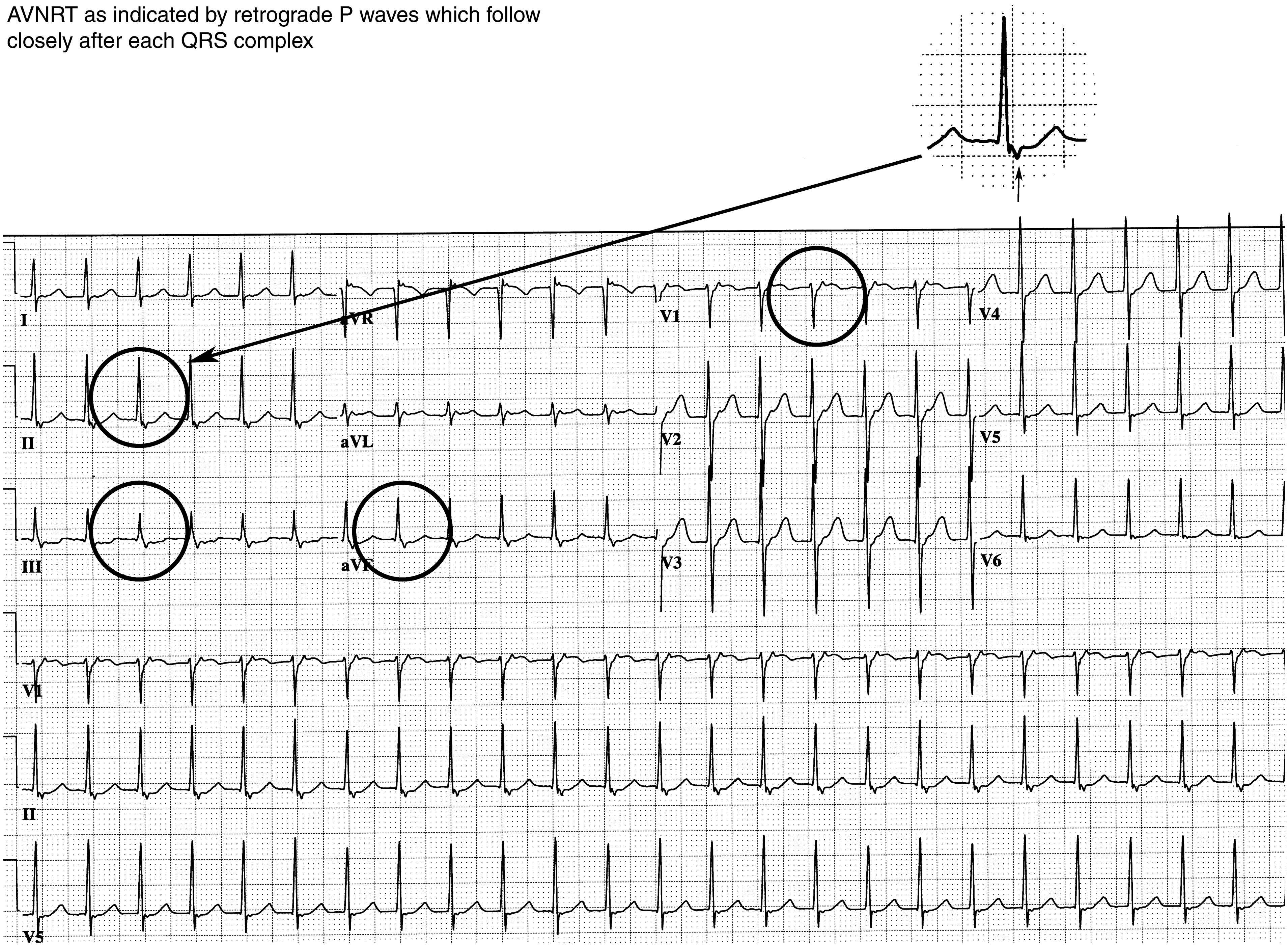
DAY 5-11

AVNRT of the common, or short RP form, as indicated by the retrograde P waves which follow the QRS complexes



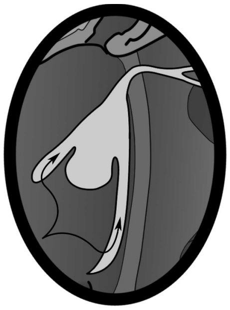
DAY 5-12

AVNRT as indicated by retrograde P waves which follow closely after each QRS complex

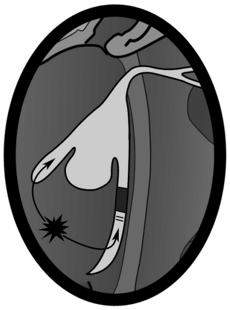


(2) Since the impulse travels down the fast pathway and back up the slow pathway, the P wave is typically closer to the next QRS complex. (Day 5-13)

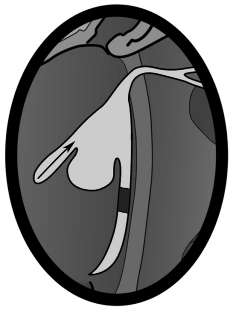
2. Heart rate
   a. The AVNRT rate is usually 120–220.
   b. The ventricular rate is almost always the same as the atrial rate.
3. ECG morphology—see figures.
4. Response to vagal maneuvers or AV nodal blocking medications—these measures frequently *terminate* the arrhythmia.



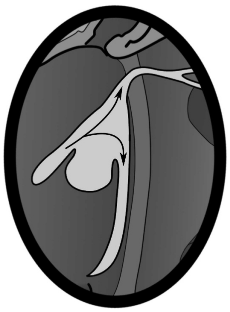
Normal conduction through the AV node.



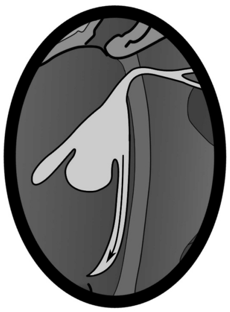
In the situation above, a fortuitously timed PAC is conducted down the fast pathway (see text). The slow pathway, with its longer repolarization time in this patient, is still refractory.



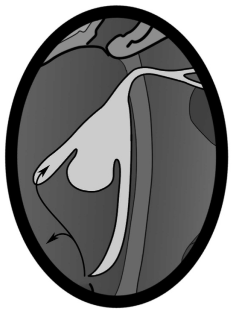
The conduction continues down the fast pathway while the slow pathway completes its repolarization.



The impulse is free to travel down the His bundle and depolarize the ventricles. Meanwhile, the slow pathway has repolarized.



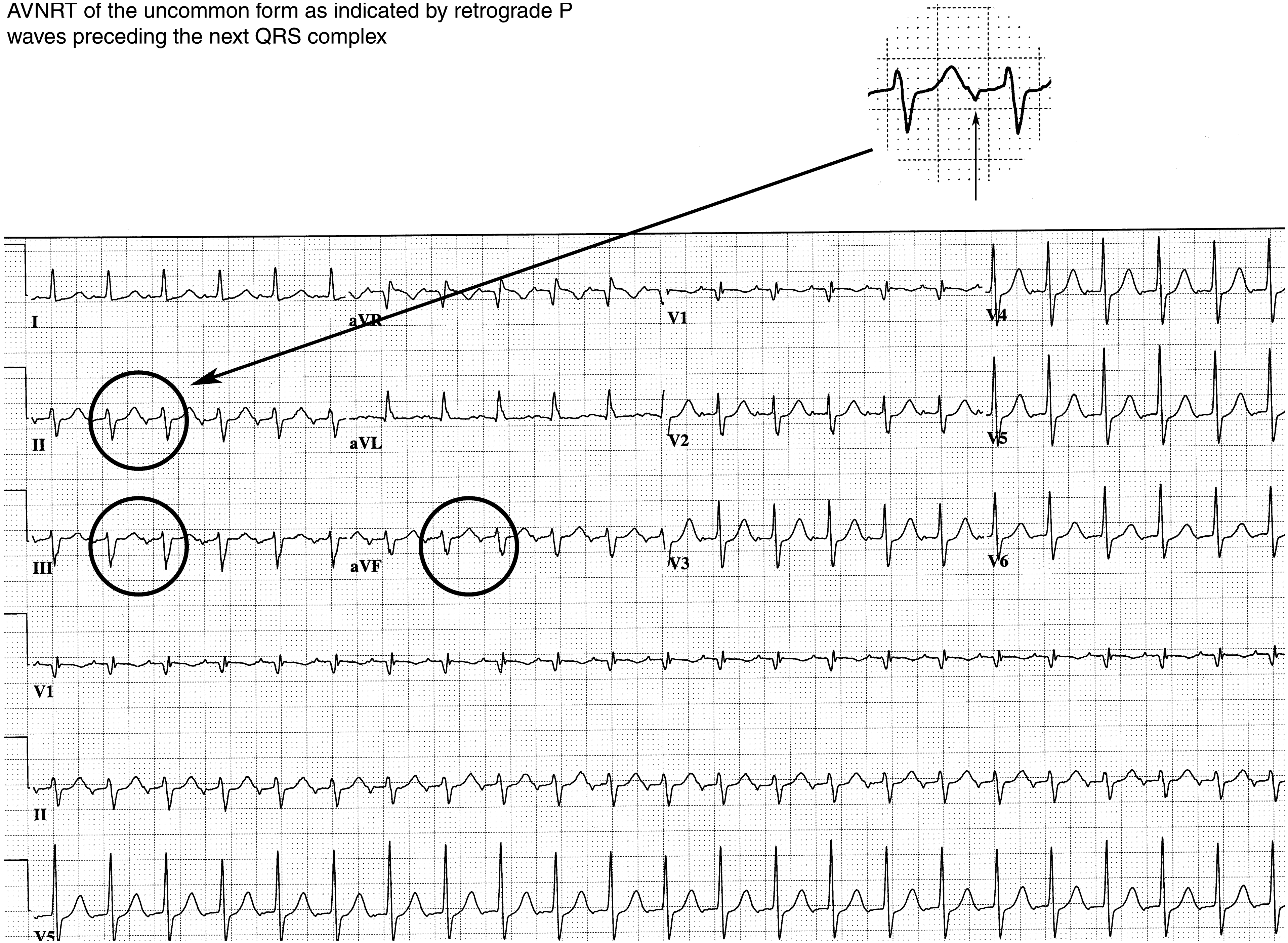
The impulse is free to travel retrograde up the slow pathway.



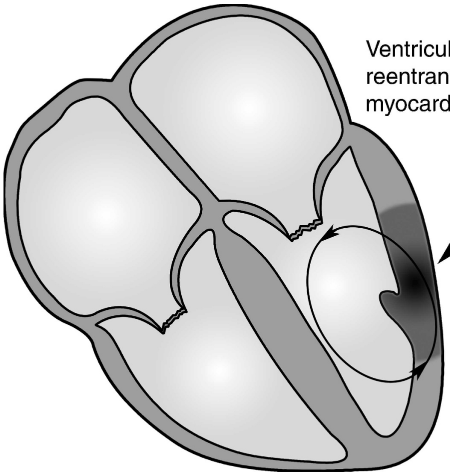
If the impulse arrives at the branch point before the next normal depolarization arrives from above, the reentry loop may sustain itself, resulting in AVNRT, in this case, of the uncommon or atypical form.

DAY 5-13

AVNRT of the uncommon form as indicated by retrograde P waves preceding the next QRS complex



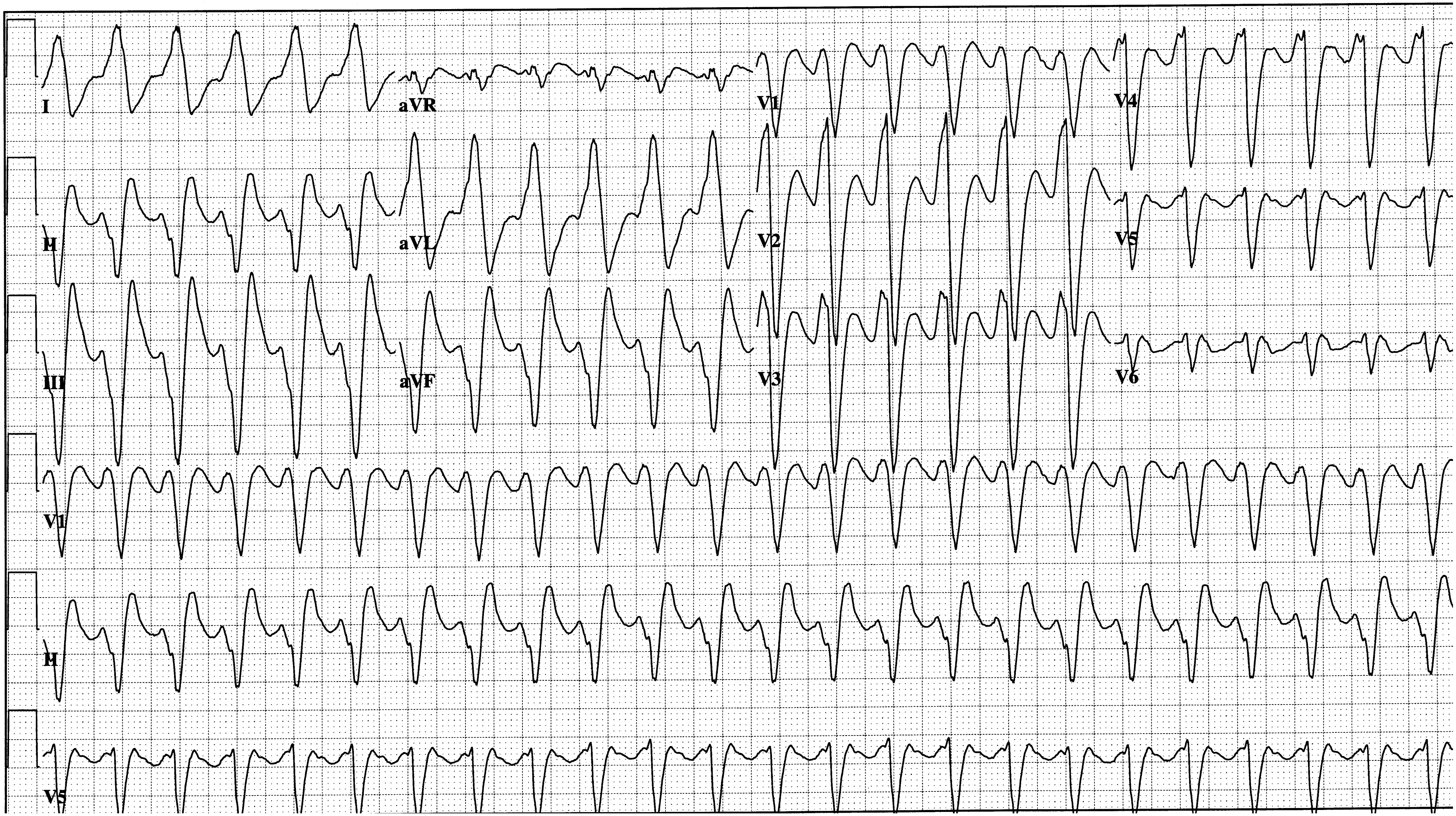
D. Ventricular tachycardia (VT)
   1. Mechanisms and causes



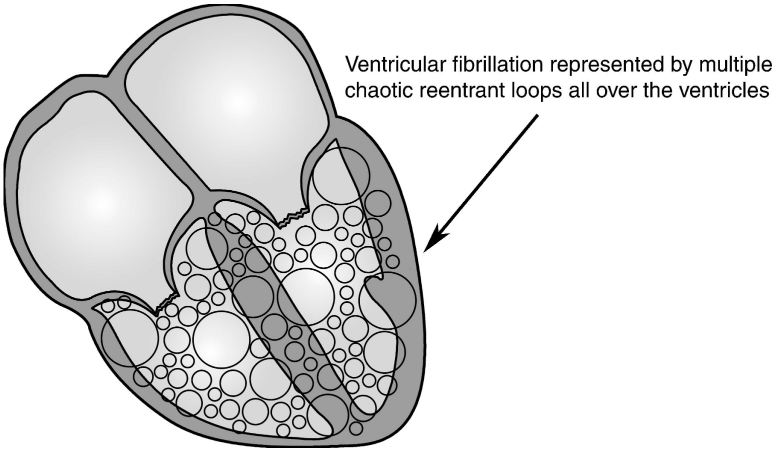
      a. Most VT (90%) is due to reentry.
      b. The reentry pathway frequently involves the edges of a previously infarcted area of myocardium, but also may be present in any condition, which causes a myocardial abnormality.
      c. VT rarely occurs in healthy individuals.
   2. Heart rate
      a. The VT rate is typically 120–220.
      b. The atrial rhythm may remain the same as it was prior to the development of VT (70% of the time, in which case there is AV dissociation), or there may be retrograde conduction to the atrium (30%, no AV dissociation).
   3. ECG morphology (Day 5-14)
      a. VT demonstrates a wide QRS morphology.
      b. For a discussion of the differentiation of wide QRS tachycardias, see the notes for Day 8.
   4. Response to vagal maneuvers—vagal maneuvers rarely have any effect on VT.

DAY 5-14

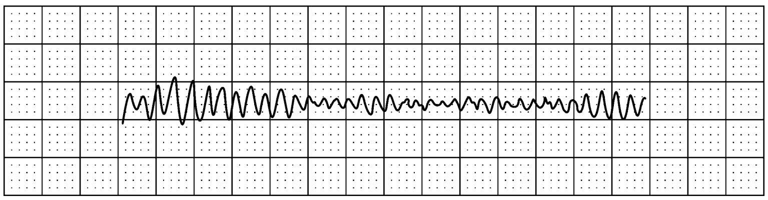
Ventricular tachycardia



E. Ventricular fibrillation (VF)
  1. Mechanisms and causes
    a. VF probably represents multiple chaotic reentrant pathways involving the entire ventricular muscle.
    b. VF occurs in patients with severe ischemia, hypoxia, metabolic abnormalities, etc.
    c. VF is obviously rapidly fatal unless defibrillated.



  2. ECG morphology—VF demonstrates an erratic baseline with no organized activity.



Typical chaotic appearance of ventricular fibrillation

F. Summary of reentrant arrhythmias

Arrhythmia	Reentrant rate	ECG description	Effects of vagal maneuvers and intravenous AV nodal blocking medications
Atrial Fib	400–600	Irregular baseline, no regular P waves, irregular ventricular response	Slows ventricular response irregularly, no effect on atrial fib
Atrial Flutter	220–320	Regular sawtooth P waves, regular ventricular response, usually even whole number divisions of atrial rate	Slows ventricular response in regular divisions of atrial rate, no effect on atrial flutter
AVNRT	120–220	One inverted P wave for each QRS, P wave usually buried in QRS complex	May terminate the AVNRT abruptly
VT	120–220	Wide QRS tachycardia (see Day 8)	No effect
VF	-	Irregular baseline with no organized ventricular activity	No effect

Sample Tracings
ECG 1

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

ST segment: ______

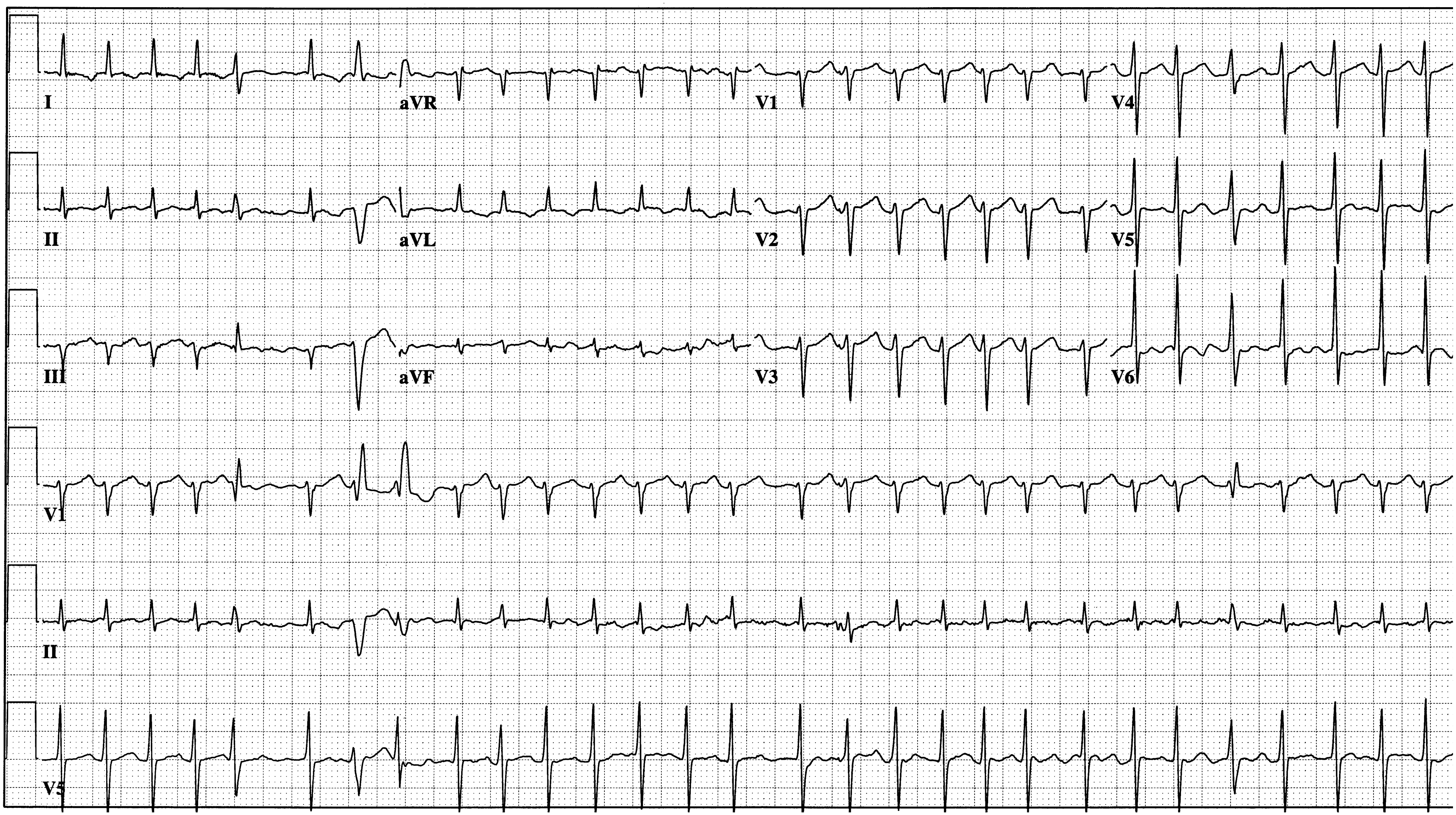
T wave: ______

QT interval: ______

U wave: ______

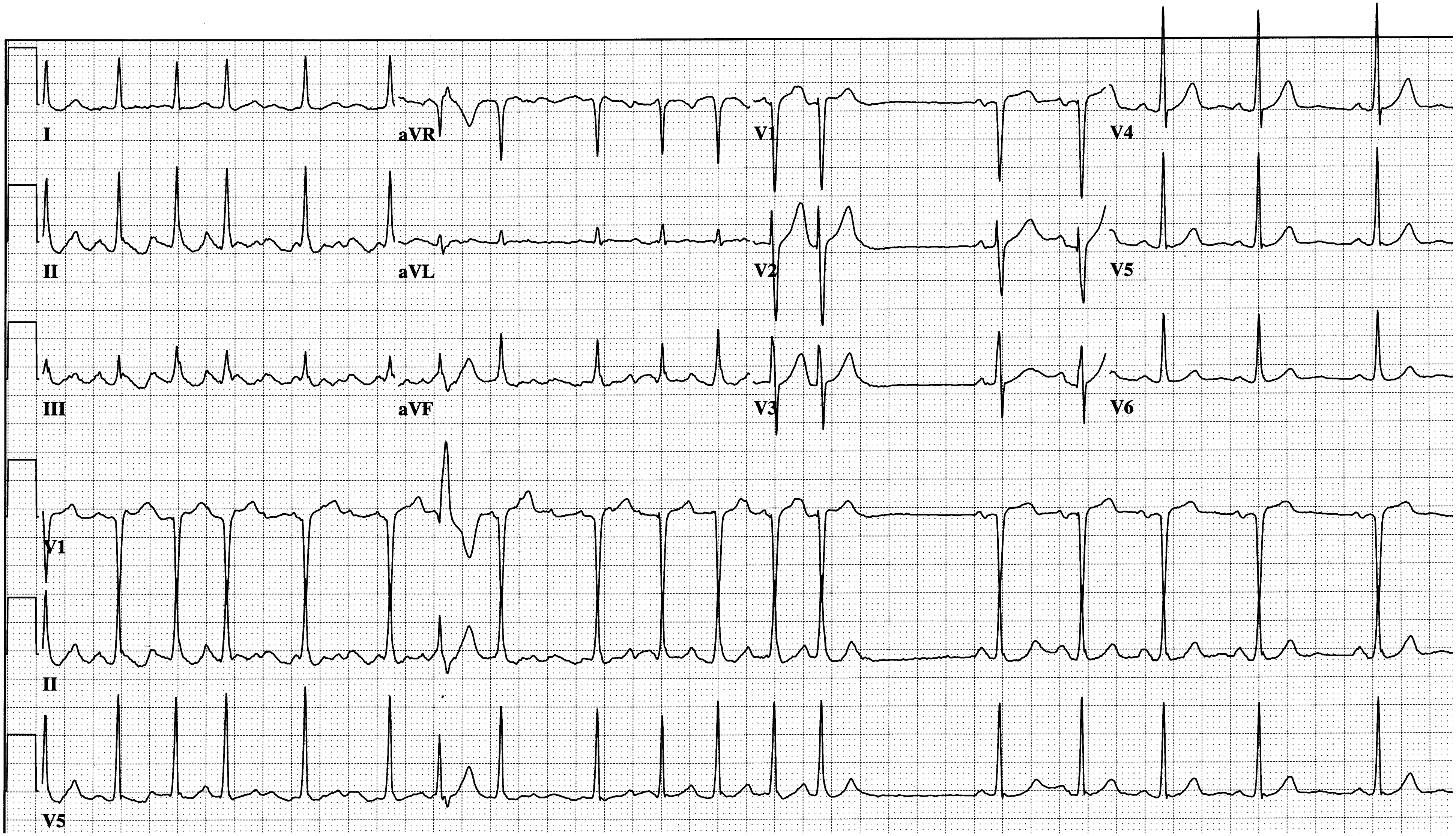
Diagnosis: ______

______



ECG 2

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG 3

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

ST segment: ______

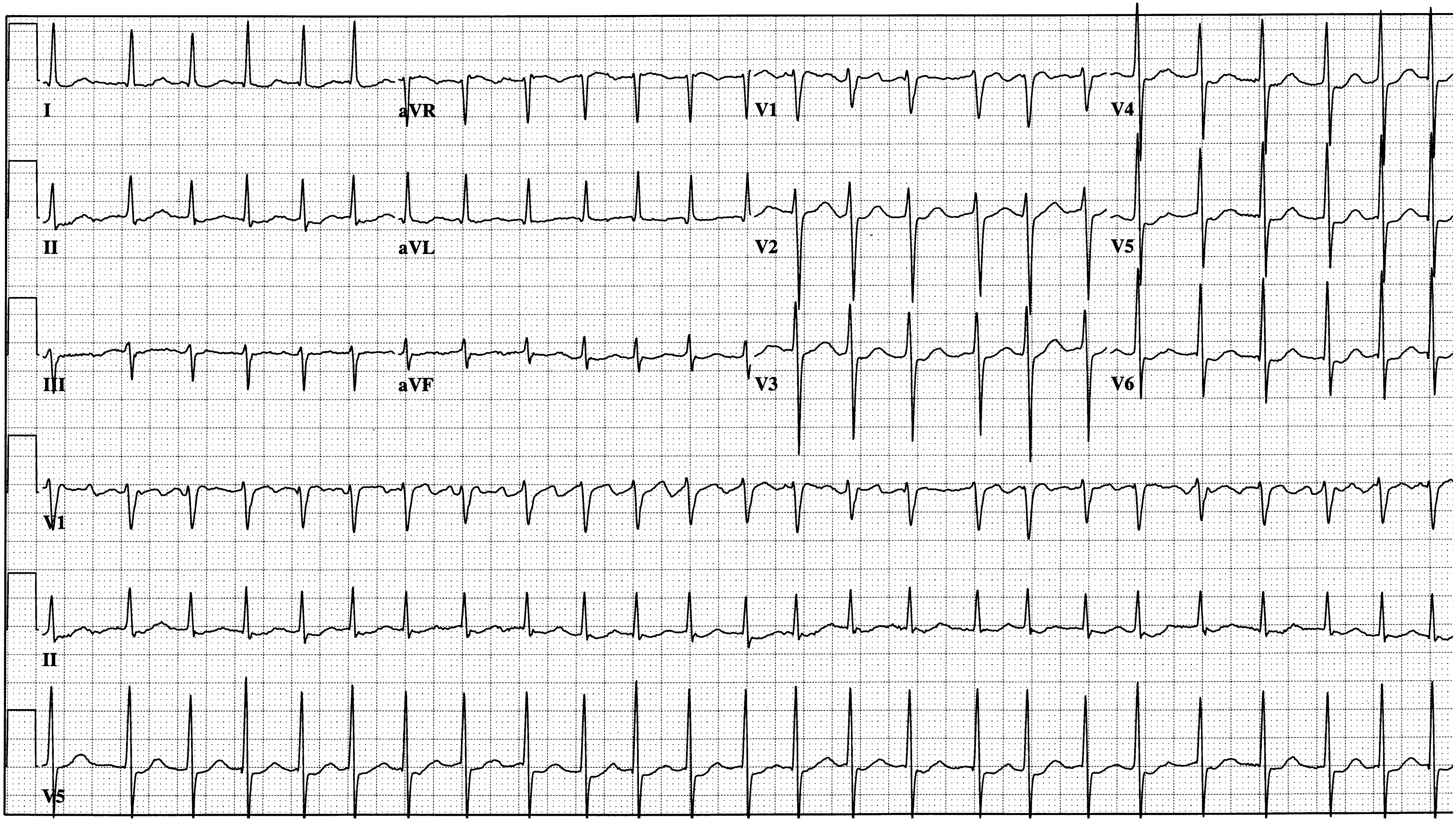
T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______

______



ECG 4

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

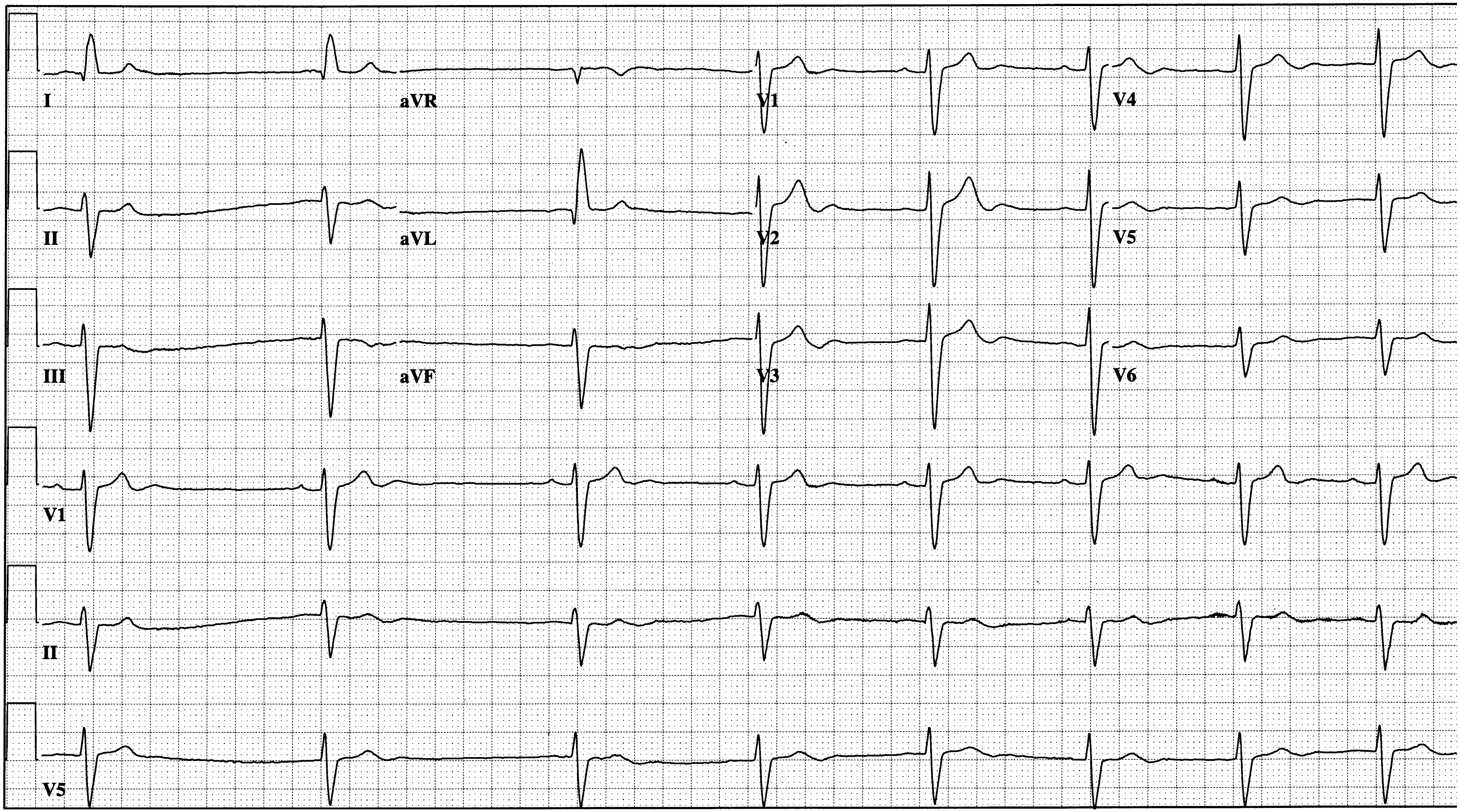
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 5

Atrial rate: ____________

Ventricular rate: ____________

Rhythm: ____________

P wave: ____________

PR interval: ____________

QRS complex:

Axis: ____________

Duration: ____________

Voltage: ____________

Morphology: ____________

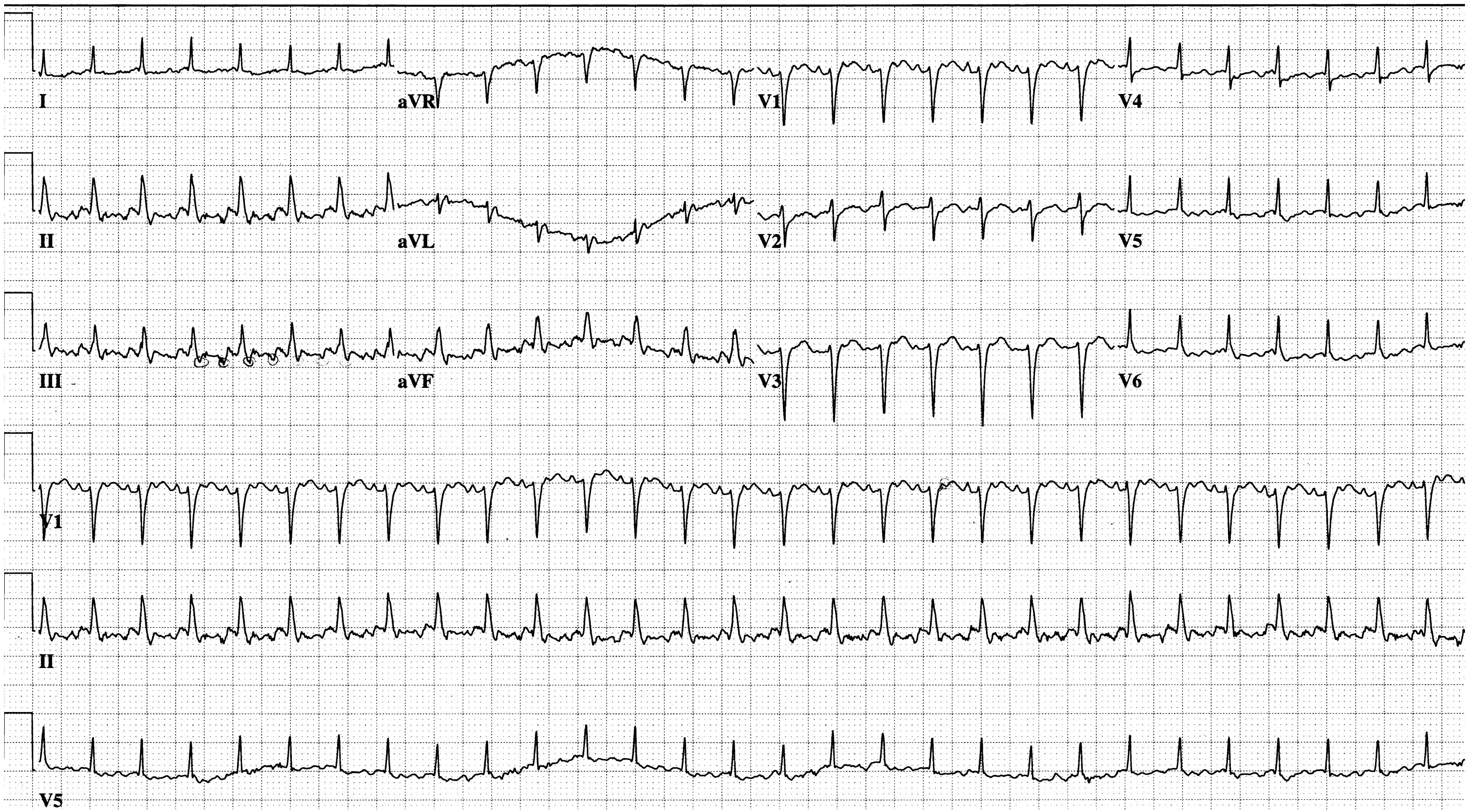
ST segment: ____________

T wave: ____________

QT interval: ____________

U wave: ____________

Diagnosis: ____________



ECG 6

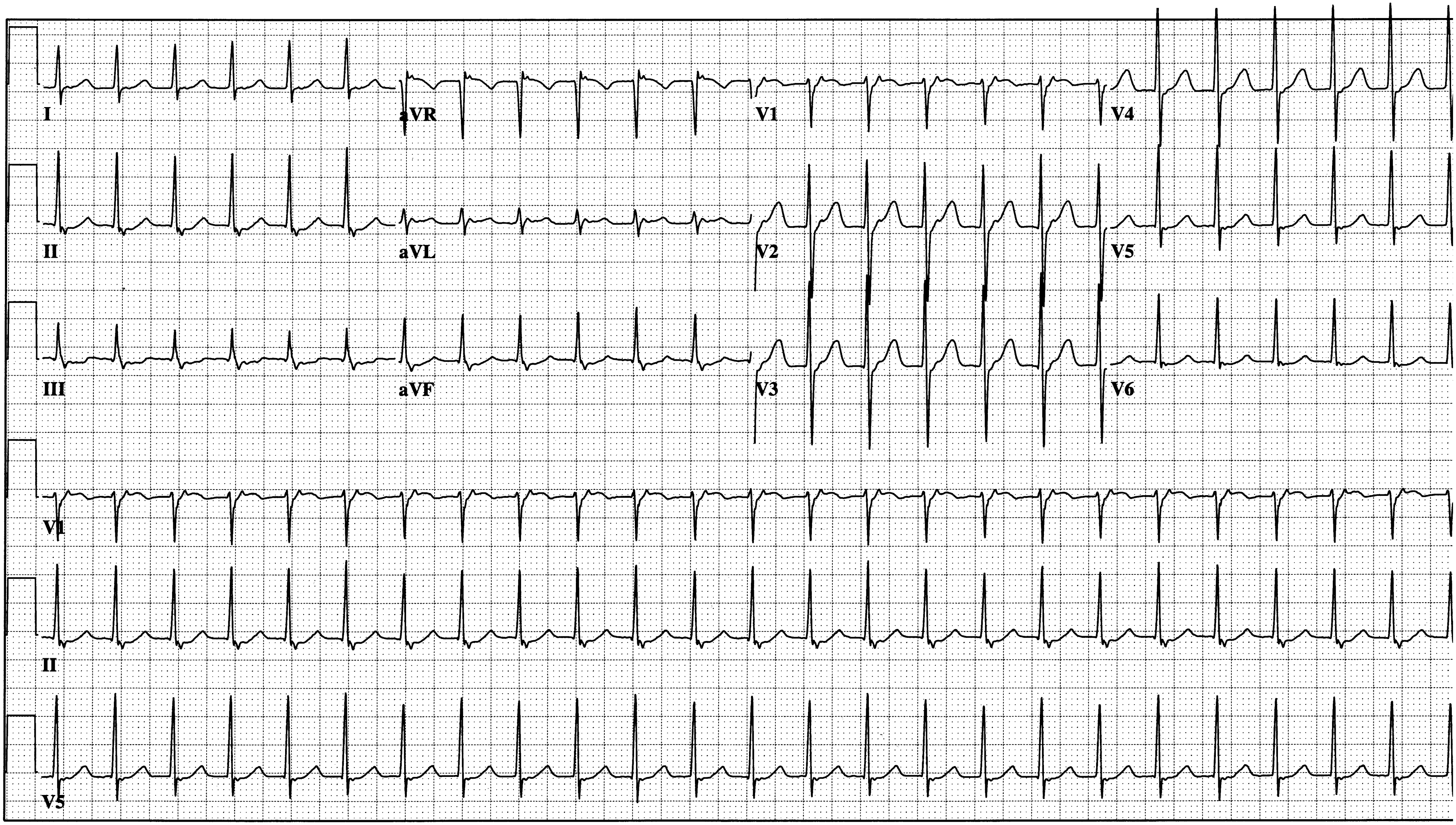
Atrial rate: ____________ QRS complex: ST segment: ____________

Ventricular rate: ____________ Axis: ____________ T wave: ____________

Rhythm: ____________ Duration: ____________ QT interval: ____________

P wave: ____________ Voltage: ____________ U wave: ____________

PR interval: ____________ Morphology: ____________ Diagnosis: ____________



ECG 7

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

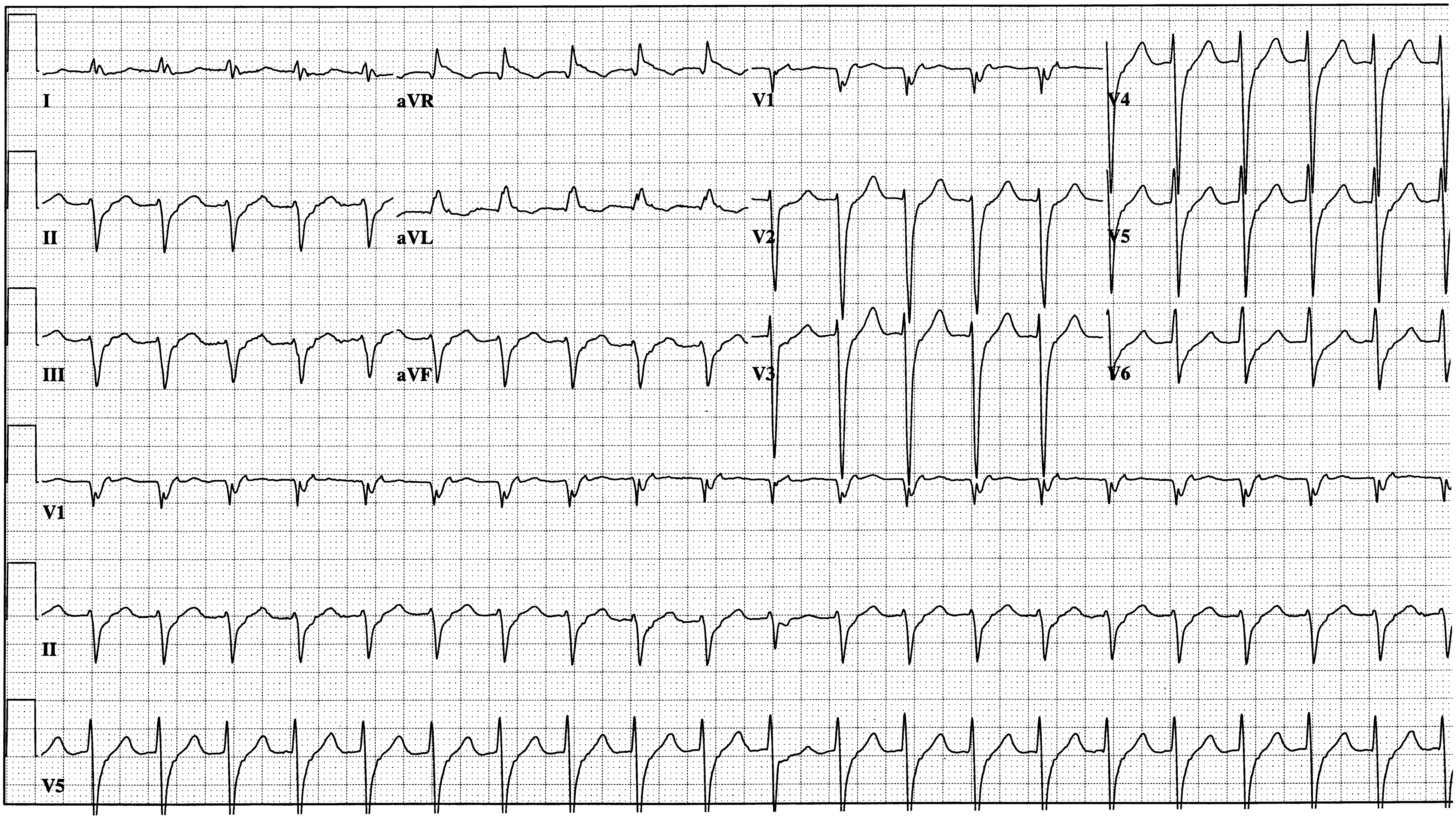
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG 8

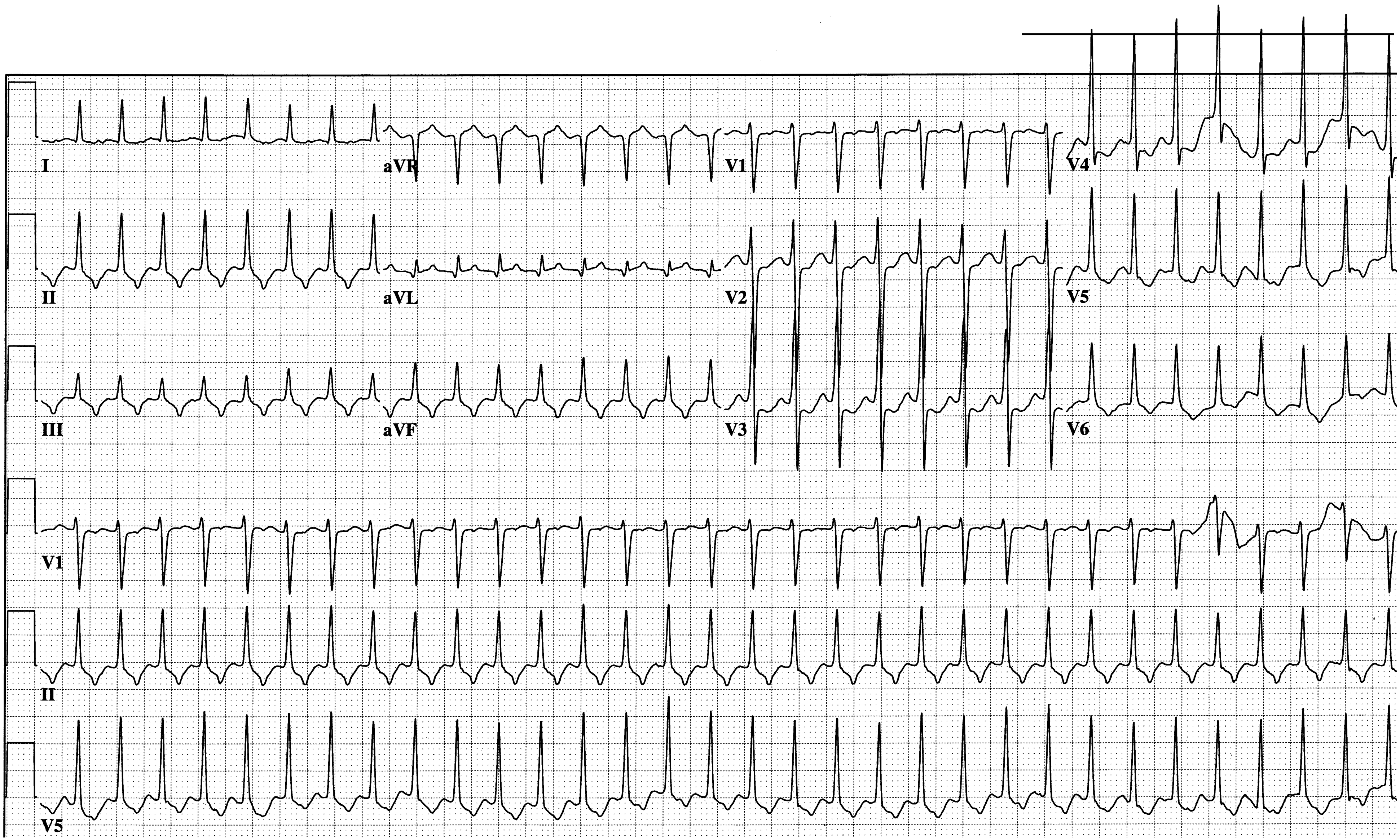
Atrial rate: ______________ QRS complex: ST segment: ______________

Ventricular rate: ______________ Axis: ______________ T wave: ______________

Rhythm: ______________ Duration: ______________ QT interval: ______________

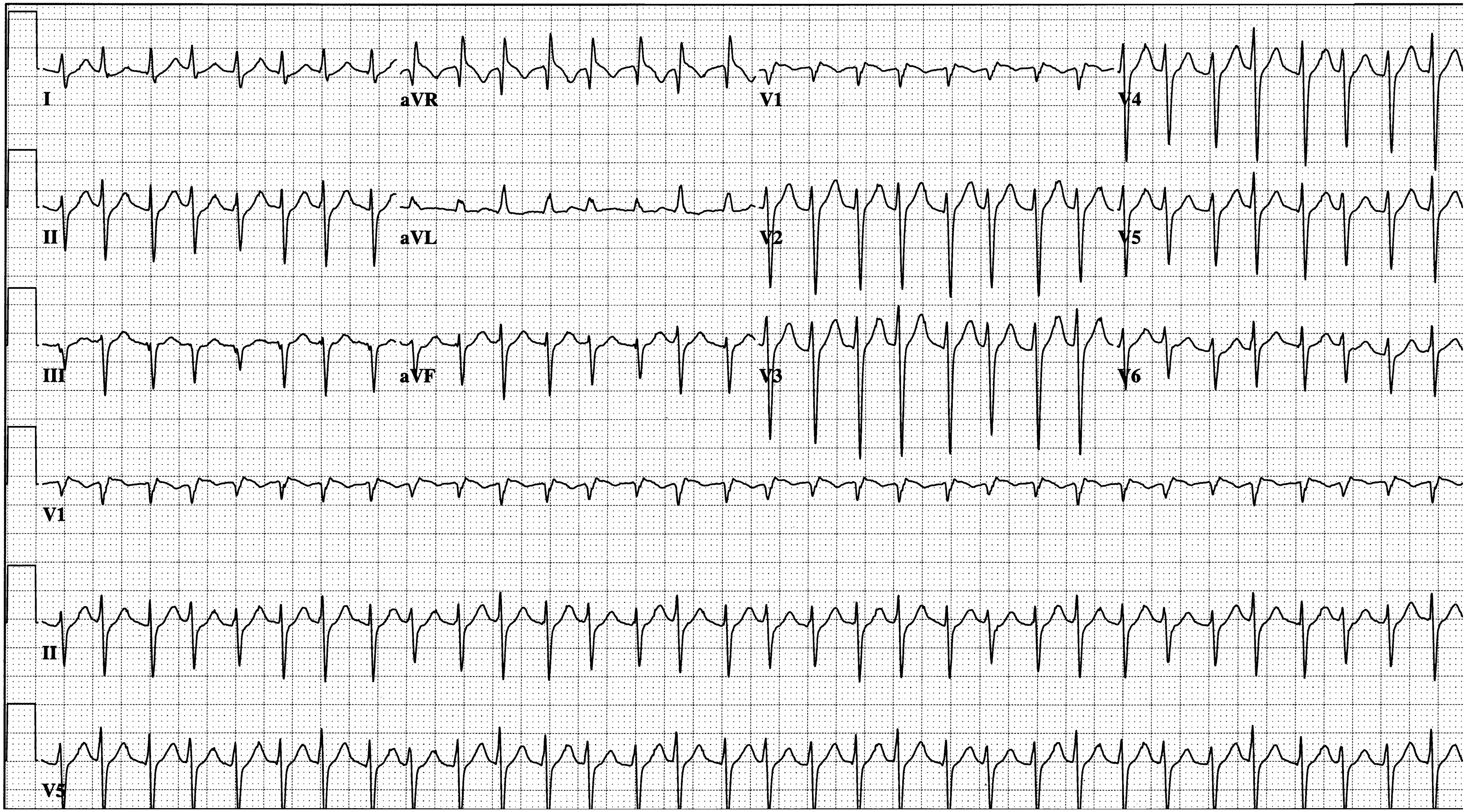
P wave: ______________ Voltage: ______________ U wave: ______________

PR interval: ______________ Morphology: ______________ Diagnosis: ______________



ECG 9

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG 10

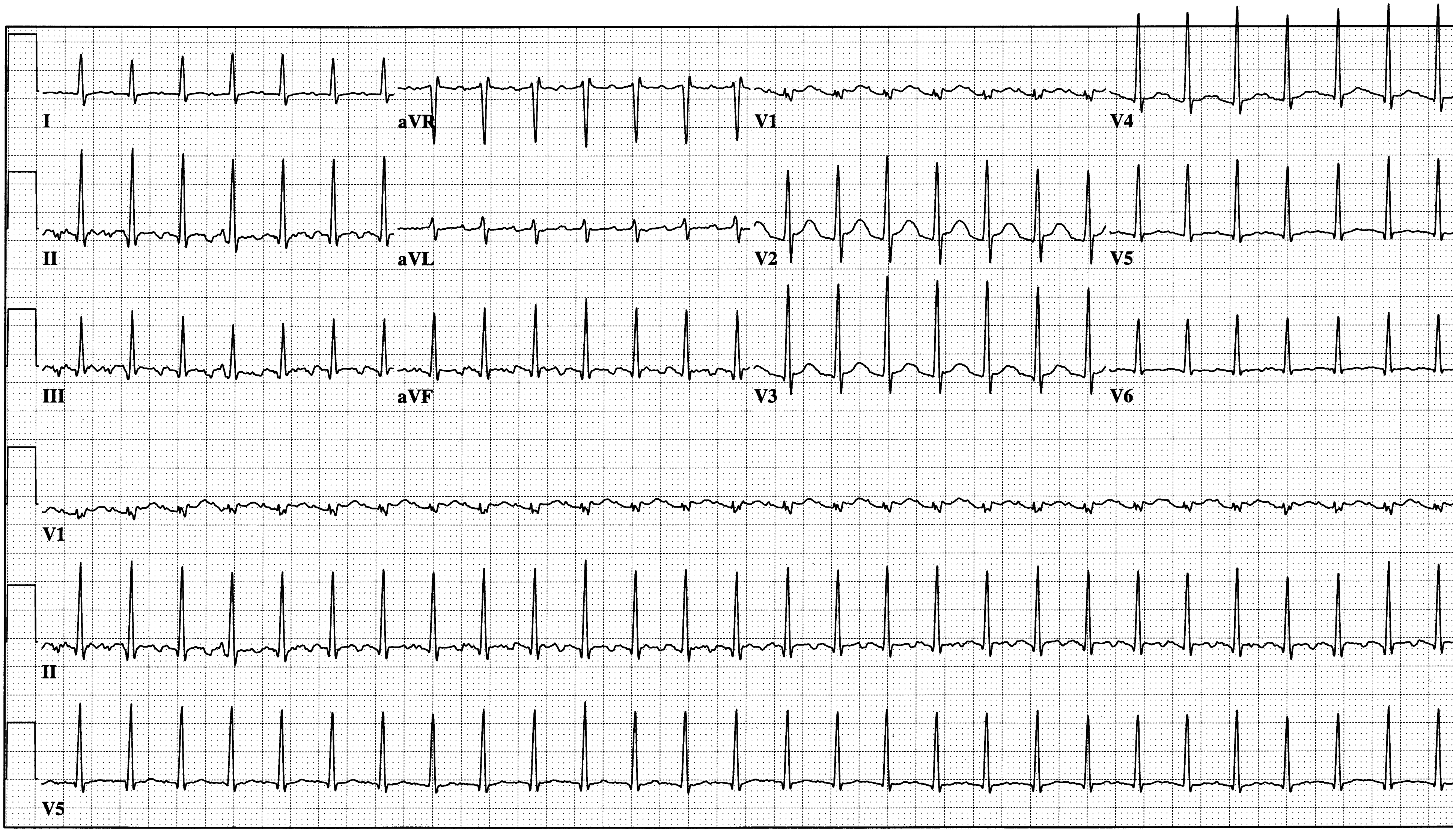
Atrial rate: ______________ QRS complex: ST segment: ______________

Ventricular rate: ______________ Axis: ______________ T wave: ______________

Rhythm: ______________ Duration: ______________ QT interval: ______________

P wave: ______________ Voltage: ______________ U wave: ______________

PR interval: ______________ Morphology: ______________ Diagnosis: ______________



ECG 11

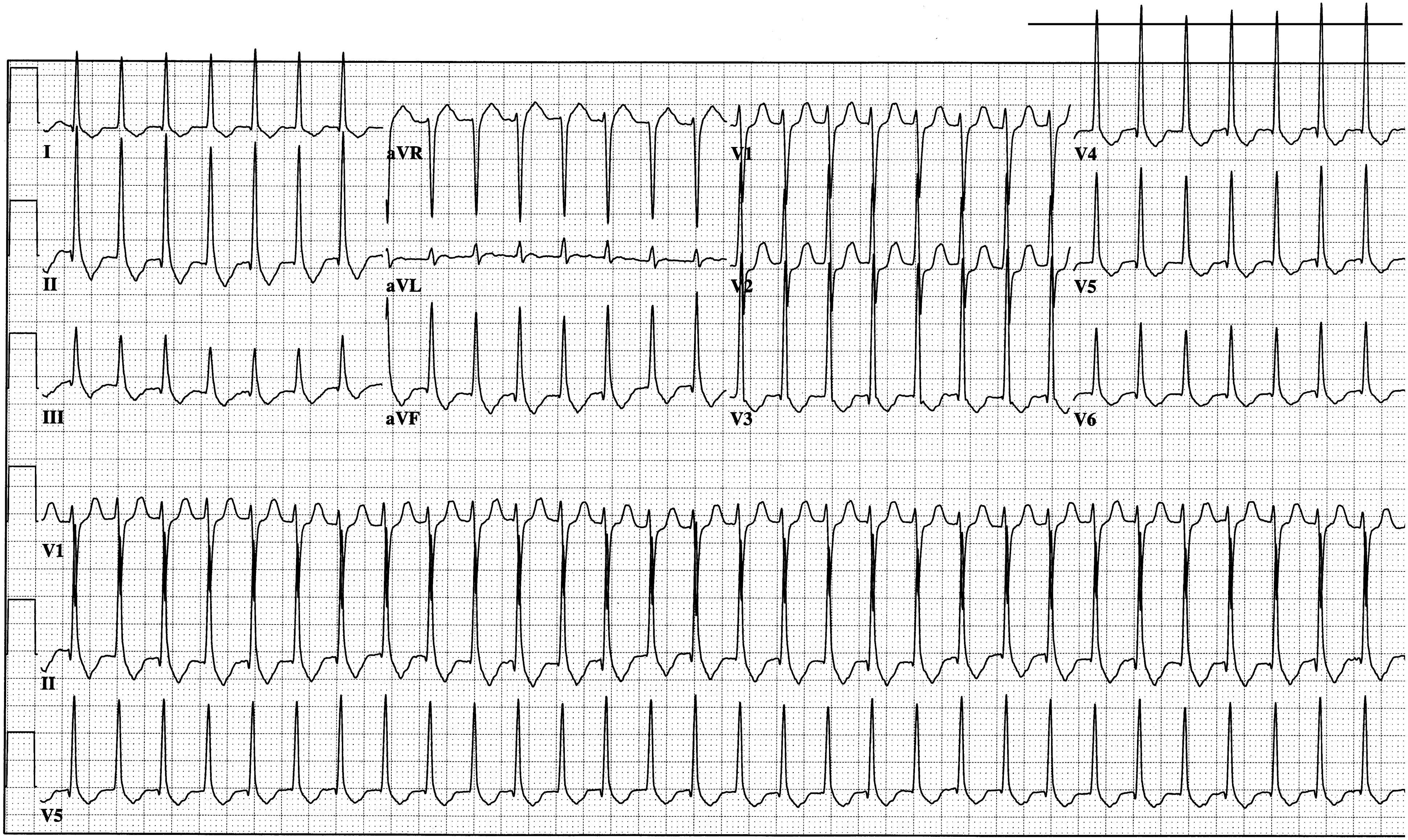
Atrial rate: ____________ QRS complex: ST segment: ____________

Ventricular rate: ____________ Axis: ____________ T wave: ____________

Rhythm: ____________ Duration: ____________ QT interval: ____________

P wave: ____________ Voltage: ____________ U wave: ____________

PR interval: ____________ Morphology: ____________ Diagnosis: ____________



ECG 12

Atrial rate: ____________

Ventricular rate: ____________

Rhythm: ____________

P wave: ____________

PR interval: ____________

QRS complex:

Axis: ____________

Duration: ____________

Voltage: ____________

Morphology: ____________

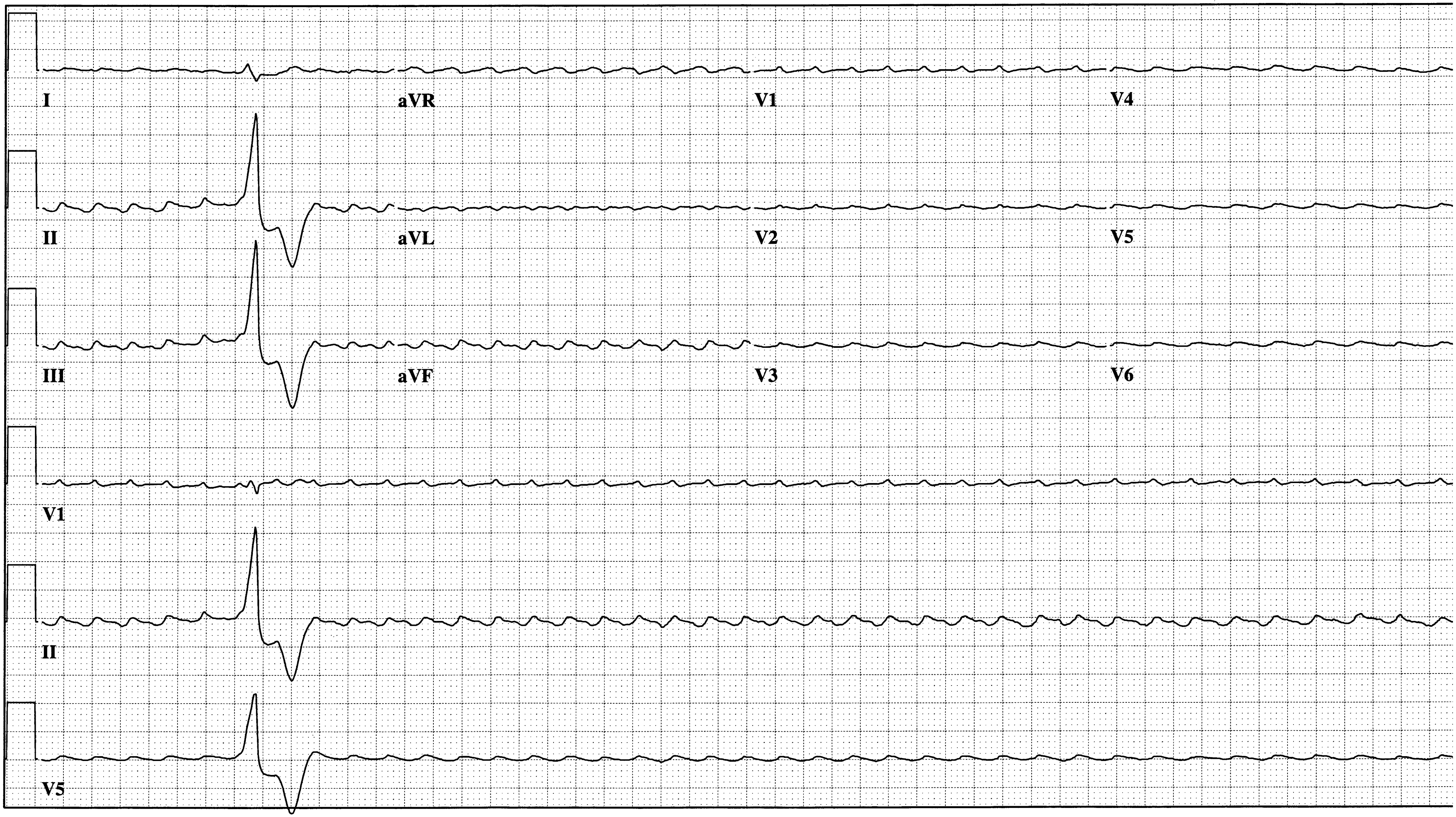
ST segment: ____________

T wave: ____________

QT interval: ____________

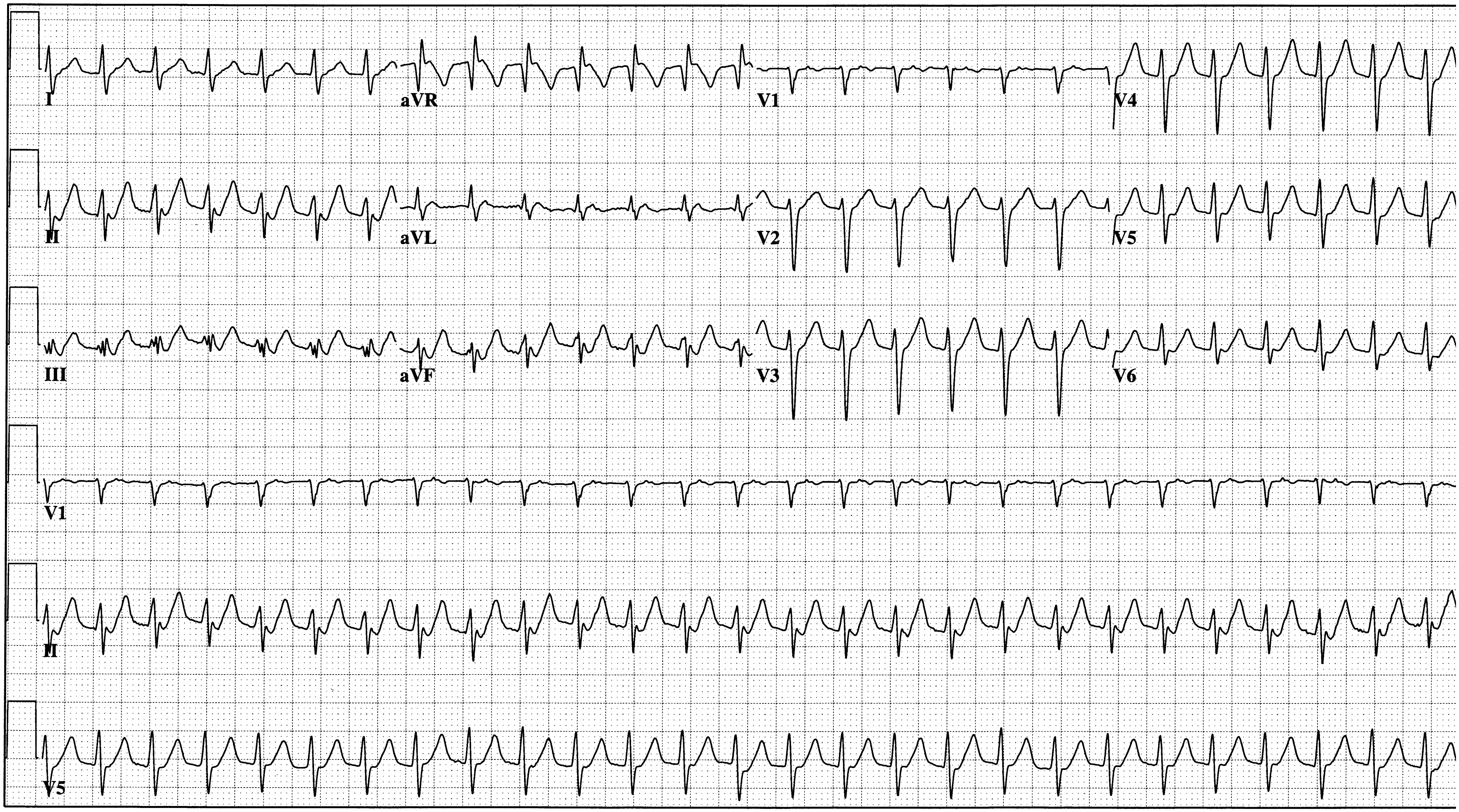
U wave: ____________

Diagnosis: ____________



ECG 13

Atrial rate:	QRS complex:	ST segment:
Ventricular rate:	Axis:	T wave:
Rhythm:	Duration:	QT interval:
P wave:	Voltage:	U wave:
PR interval:	Morphology:	Diagnosis:



ECG 14

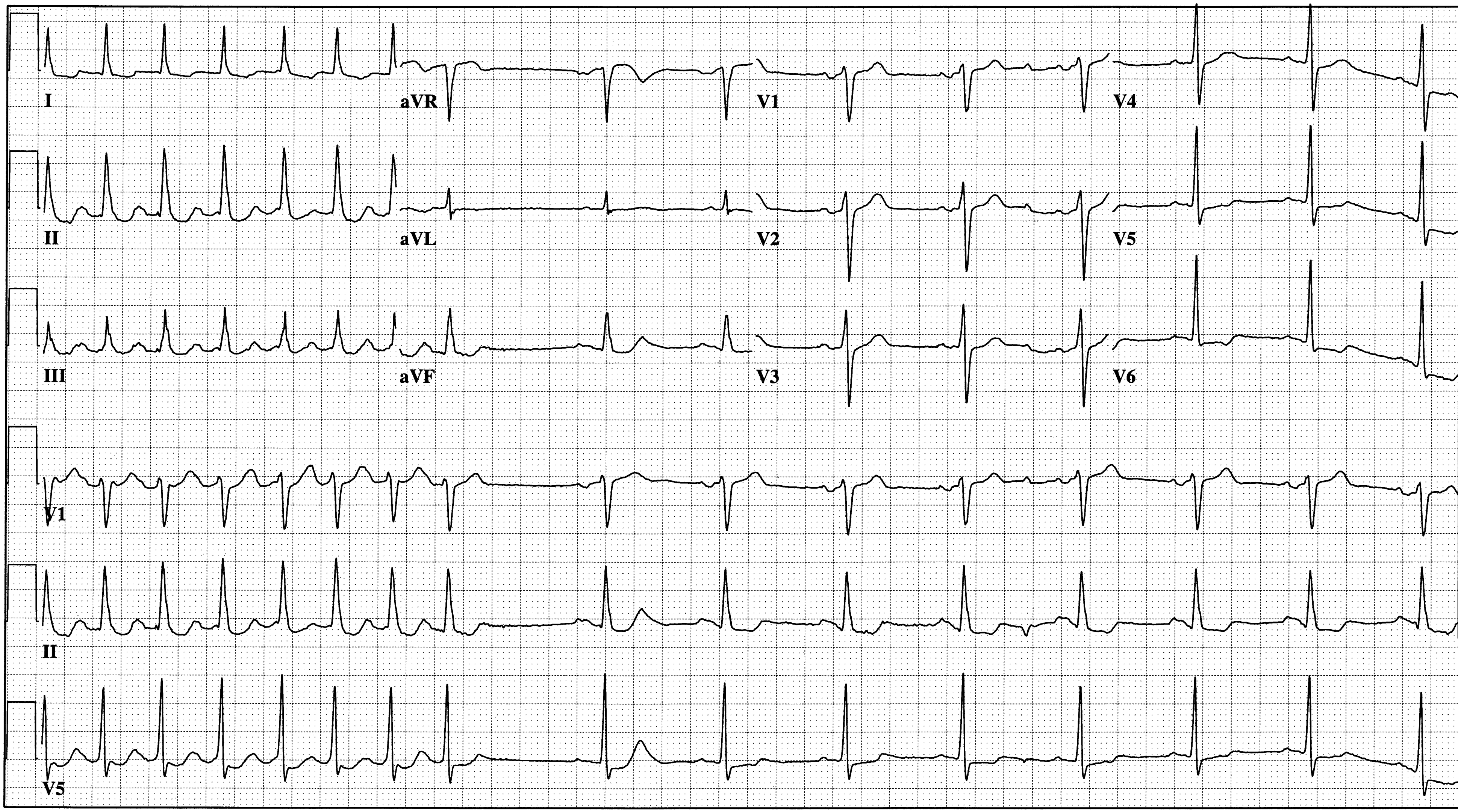
Atrial rate: ______________ QRS complex: ST segment: ______________

Ventricular rate: ______________ Axis: ______________ T wave: ______________

Rhythm: ______________ Duration: ______________ QT interval: ______________

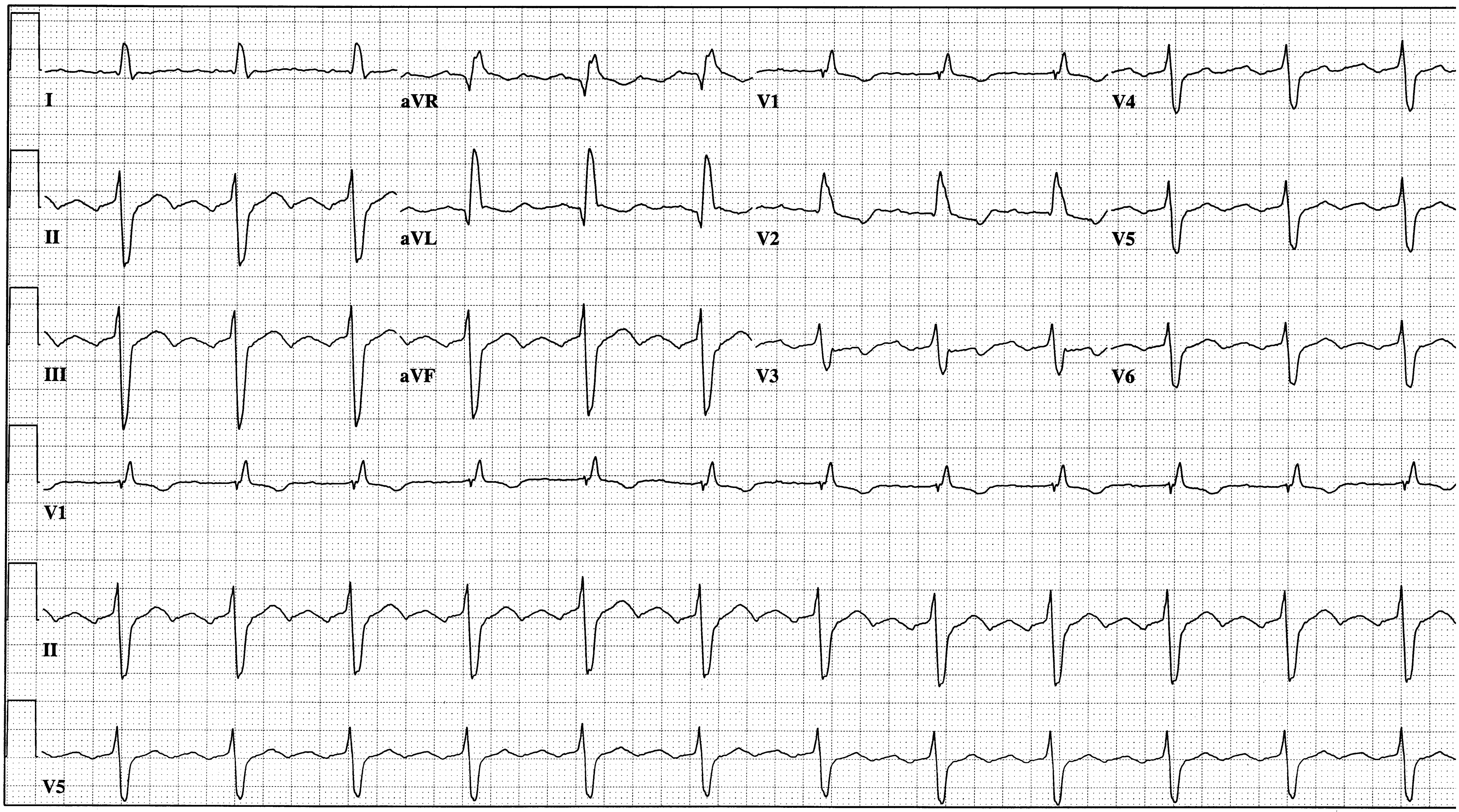
P wave: ______________ Voltage: ______________ U wave: ______________

PR interval: ______________ Morphology: ______________ Diagnosis: ______________



ECG 15

Atrial rate: ________	QRS complex:	ST segment: ________
Ventricular rate: ________	Axis: ________	T wave: ________
Rhythm: ________	Duration: ________	QT interval: ________
P wave: ________	Voltage: ________	U wave: ________
PR interval: ________	Morphology: ________	Diagnosis: ________



ECG 16

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

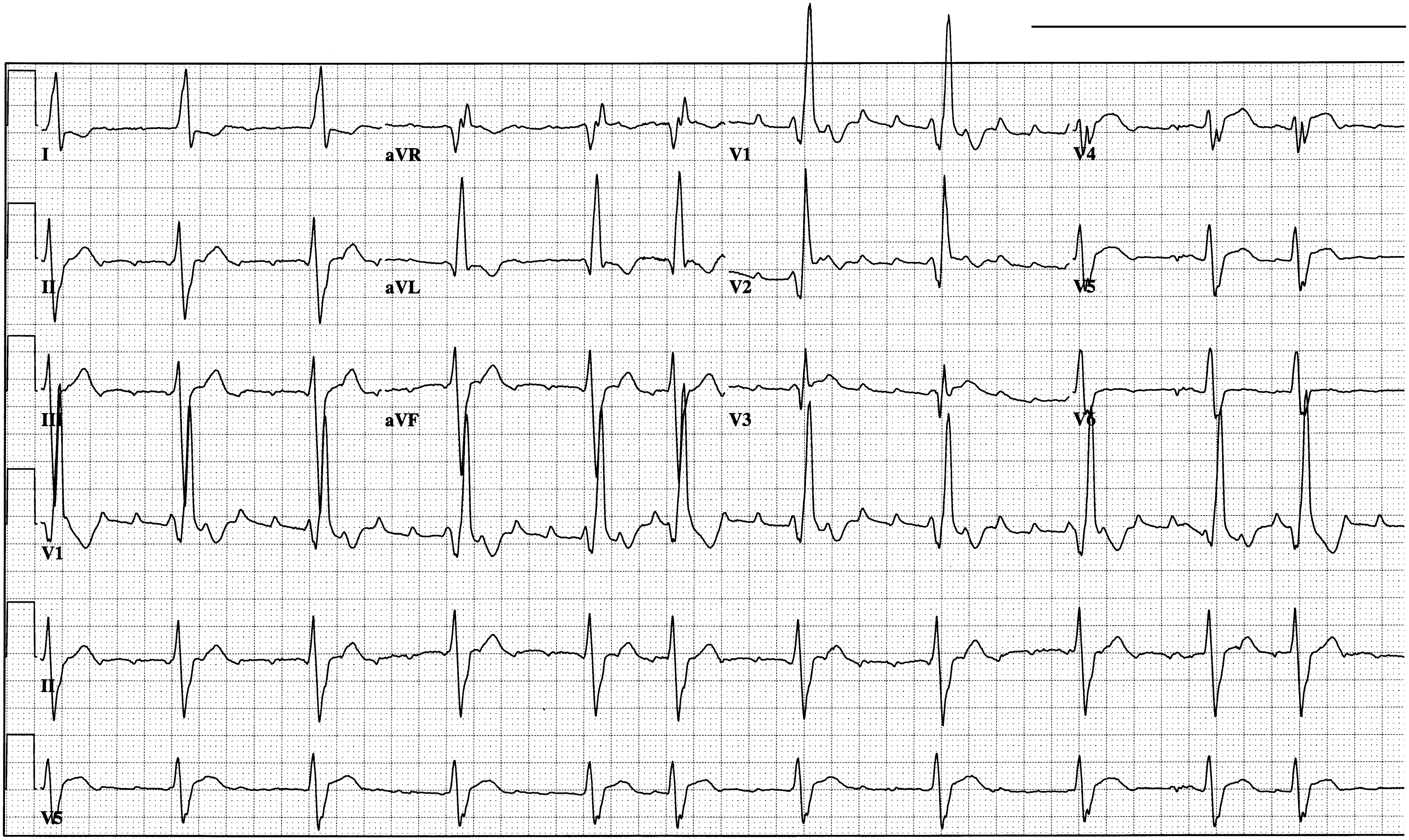
ST segment: ______________________

T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________



ECG 17

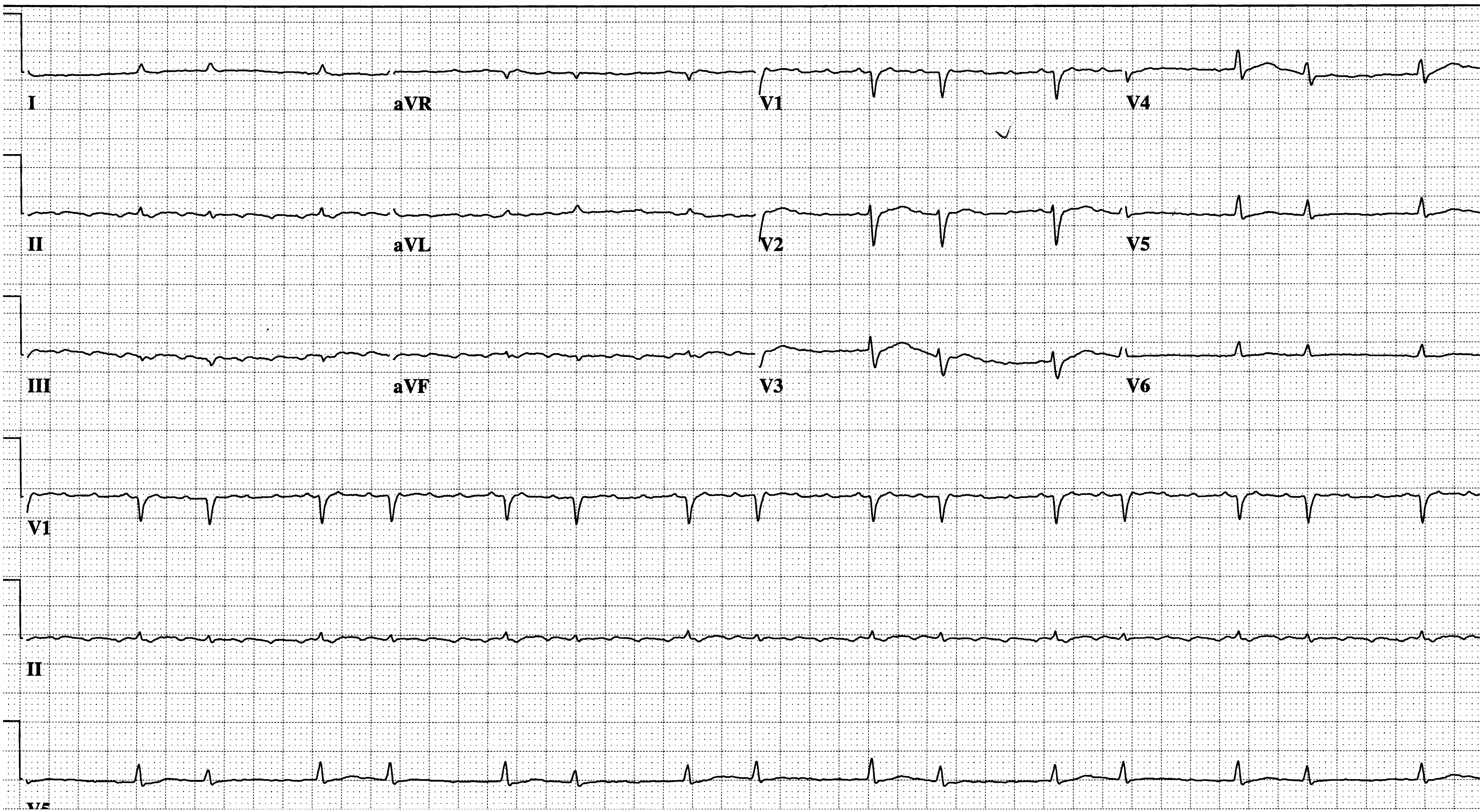
Atrial rate: ____________________ QRS complex: ST segment: ____________________

Ventricular rate: ____________________ Axis: ____________________ T wave: ____________________

Rhythm: ____________________ Duration: ____________________ QT interval: ____________________

P wave: ____________________ Voltage: ____________________ U wave: ____________________

PR interval: ____________________ Morphology: ____________________ Diagnosis: ____________________



ECG 18

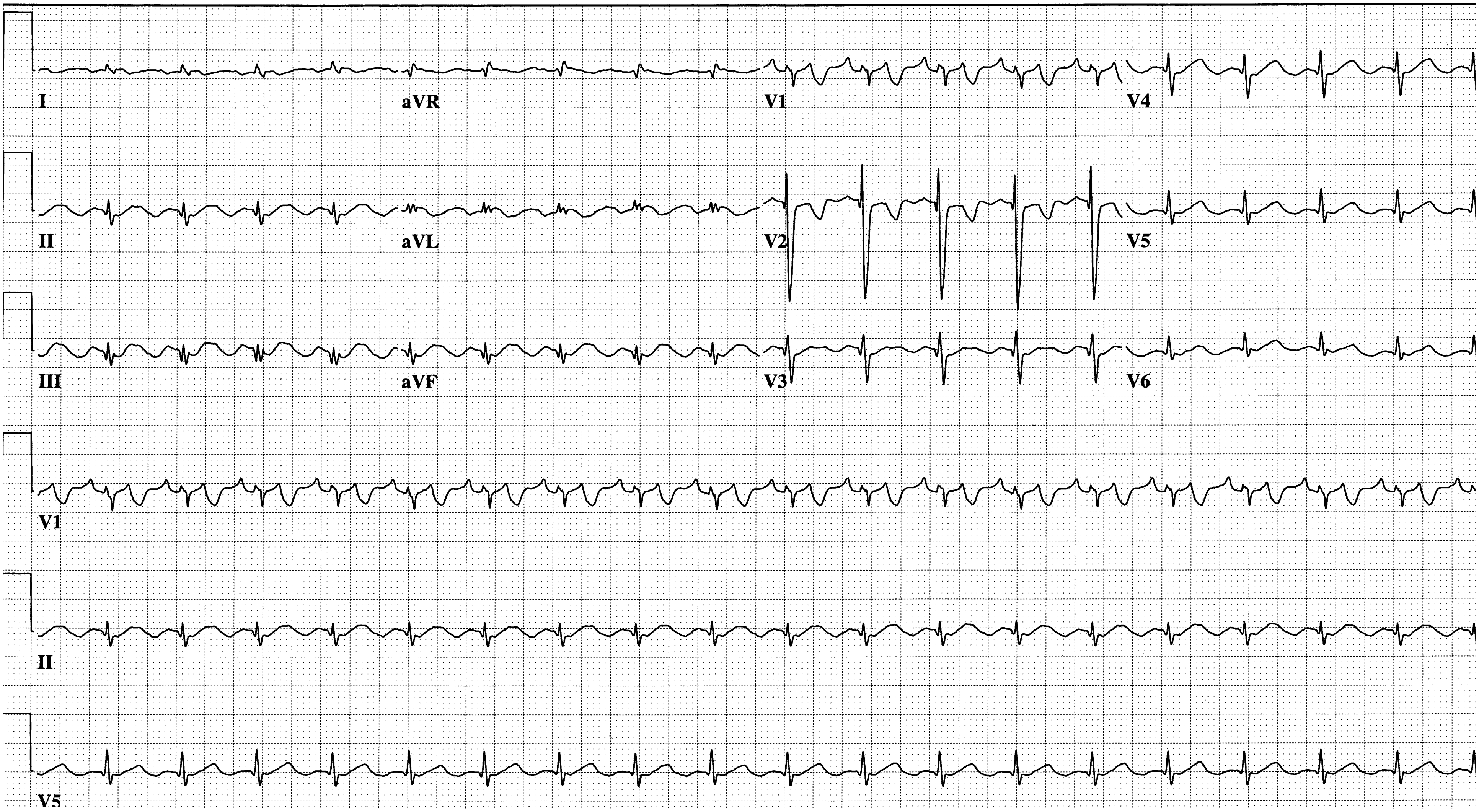
Atrial rate: ______________ QRS complex: ST segment: ______________

Ventricular rate: ______________ Axis: ______________ T wave: ______________

Rhythm: ______________ Duration: ______________ QT interval: ______________

P wave: ______________ Voltage: ______________ U wave: ______________

PR interval: ______________ Morphology: ______________ Diagnosis: ______________



ECG 19

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

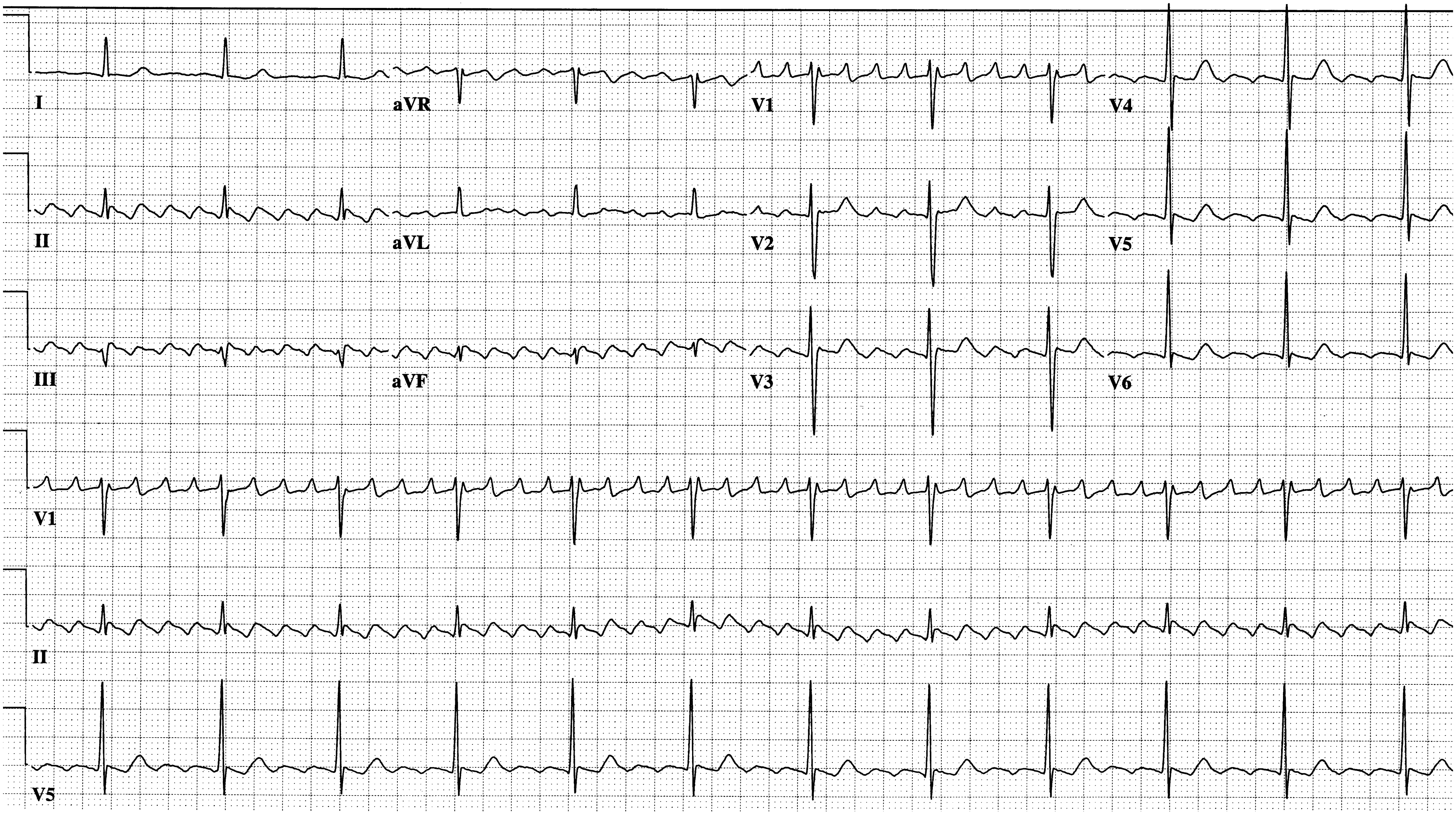
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 20

Atrial rate: ________ QRS complex: ST segment: ________

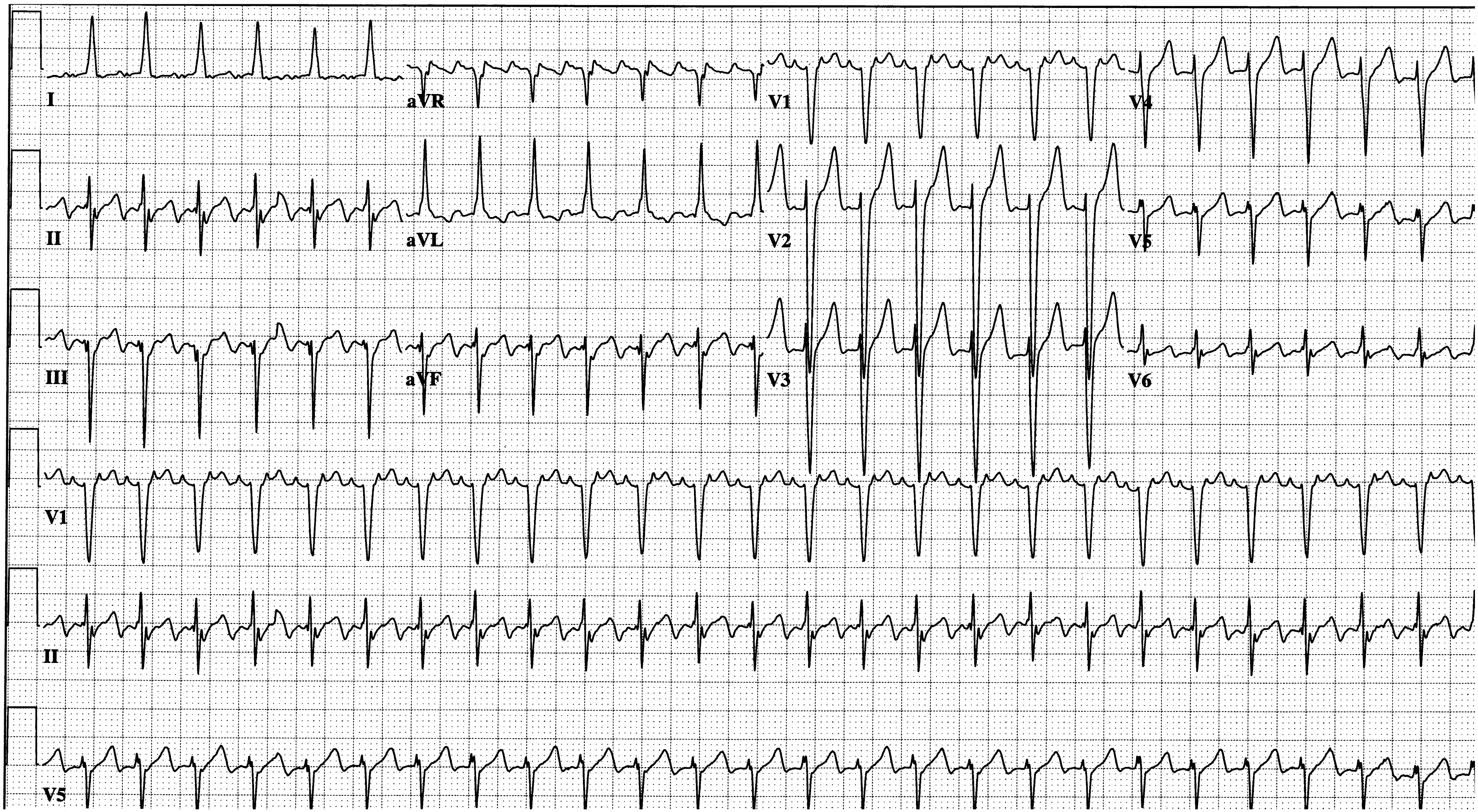
Ventricular rate: ________ Axis: ________ T wave: ________

Rhythm: ________ Duration: ________ QT interval: ________

P wave: ________ Voltage: ________ U wave: ________

PR interval: ________ Morphology: ________ Diagnosis: ________

____



Reentrant Arrhythmias

Interpretations of Sample Tracings
ECG 1

Atrial rate:
Ventricular rate: 175
Rhythm: Atrial fibrillation with rapid ventricular response
P wave:
PR interval:
QRS complex:
  Axis: 0°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
  ST segment: Normal
T wave: Nonspecific changes
QT interval: 270 msec
U wave:
Diagnosis: Atrial fibrillation with rapid ventricular response. Some complexes are conducted aberrantly.

ECG 2

Atrial rate:
Ventricular rate: 108
Rhythm: Atrial fibrillation with rapid ventricular response converting to sinus rhythm
P wave: Normal in sinus rhythm
PR interval: 160 msec in sinus rhythm
QRS complex:
  Axis: 45°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 330 msec
U wave:
Diagnosis: The first 2/3 of the ECG shows atrial fibrillation with rapid ventricular response that then converts to sinus rhythm. This ECG demonstrates the paroxysmal nature of typical atrial fibrillation.

ECG 3

Atrial rate:
Ventricular rate: 148
Rhythm: Atrial fibrillation with rapid ventricular response
P wave:
PR interval:
  QRS complex:
  Axis: 0°
  Duration: 90 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Moderate diffuse ST segment depression
T wave: Nonspecific changes
QT interval: 310 msec
U wave:
Diagnosis: Atrial fibrillation with rapid ventricular response and ST-T wave changes possibly indicating ischemia

ECG 4

Atrial rate: 46
Ventricular rate: 46
Rhythm: Sinus bradycardia with sinus arrhythmia
P wave: Normal
PR interval: 180 msec
QRS complex:
  Axis: –60°
  Duration: 140 msec, with a nonspecific IVCD
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval: 430 msec
U wave: Prominent U wave in V_2 to V_4
Diagnosis: Sinus bradycardia with sinus arrhythmia, left axis deviation, a nonspecific IVCD. Sinus arrhythmia is a term used when there is more than a 10% variation in the beat to beat interval.

ECG 5

Atrial rate: 350
Ventricular rate: 175
Rhythm: Atrial flutter with 2:1 AV block
P wave:
PR interval:

QRS complex:
  Axis: 60°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Delayed precordial transition
ST segment: Normal
T wave: Normal
QT interval: 250 msec
U wave:
Diagnosis: Atrial flutter with 2:1 AV block and a possible old anteroseptal MI. This example of atrial flutter has a much faster atrial rate than typical flutter. Most of these arrhythmias have been demonstrated to have reentrant pathways in other locations than classical flutter. There is also delayed precordial transition suggesting a previous anteroseptal MI. Finally, leads V_2 and V_3 are probably reversed.

ECG 6

Atrial rate: 145
Ventricular rate: 145
Rhythm: AVNRT of the common or typical form
P wave:
PR interval:
QRS complex:
  Axis: 60°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Nonspecific ST changes
T wave: Normal
QT interval: 290 msec
U wave:
Diagnosis: AVNRT of the common or typical form with tiny retrograde P waves easily discernable in II, III, aVF, and V_1.

ECG 7

Atrial rate: 126
Ventricular rate: 126
Rhythm: AVNRT of the common or typical form
P wave:
PR interval:
QRS complex:
  Axis: –90°
  Duration: 150 msec with a nonspecific IVCD
  Voltage: Normal
  Morphology: Normal

ST segment:
T wave:
QT interval: 350 msec
U wave:
Diagnosis: AVNRT of the common or typical form, left axis deviation, and a nonspecific IVCD. There are retrograde P waves visible after each QRS complex in II, III, and aVF.

ECG 8

Atrial rate: 195
Ventricular rate: 195
Rhythm: Probable AVNRT of the uncommon or atypical form
P wave:
PR interval:
QRS complex:
- **Axis:** 60°
- **Duration:** 80 msec
- **Voltage:** Normal
- **Morphology:** Normal

ST segment: Diffuse ST segment depression
T wave: Inverted in multiple leads
QT interval: 240 msec
U wave:
Diagnosis: Probable AVNRT of the uncommon or atypical form. If one considers the retrograde P waves to be represented by the deeply inverted portion of the complexes in II, III, and aVF, then this diagnosis is appropriate. In any case, this arrhythmia is too regular to be atrial fibrillation and too fast to represent classical atrial flutter. Intravenous adenosine administration would almost certainly yield a diagnosis.

ECG 9

Atrial rate: 195
Ventricular rate: 195
Rhythm: AVNRT of the common or typical form
P wave:
PR interval:
QRS complex:
- **Axis:** −75°
- **Duration:** 80 msec
- **Voltage:** Normal
- **Morphology:** Has deep persistent S waves across the precordial leads

ST segment: Normal
T wave: Normal
QT interval: 240 msec
U wave:

Diagnosis: AVNRT of the common or typical form, left axis deviation, and deep persistent S waves across the precordial leads consistent with chronic lung disease. Retrograde P waves are present at the end of the QRS complexes in V_1.

ECG 10

Atrial rate: 170
Ventricular rate: 170
Rhythm: Probable AVNRT of the uncommon or atypical form
P wave:
PR interval:
QRS complex:
  Axis: 60°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Nonspecific changes
QT interval: 270 msec
U wave:
Diagnosis: Probable AVNRT of the uncommon or atypical form. The retrograde P waves are probably present midway between the QRS complexes in II, III, and aVF. The other possible diagnosis would be atypical atrial flutter with 2:1 AV conduction. Intravenous adenosine administration would probably clarify the diagnosis.

ECG 11

Atrial rate: 185
Ventricular rate: 185
Rhythm: Probable AVNRT of the uncommon or atypical form
P wave:
PR interval:
QRS complex:
  Axis: 60°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Nonspecific changes
T wave:
QT interval: 240 msec
U wave:
Diagnosis: Probable AVNRT of the uncommon or atypical form. What are probably retrograde P waves can be seen best in II midway between the R waves. The rhythm is too regular to be atrial fibrillation and too fast to be atrial flutter. IV adenosine would facilitate a diagnosis.

ECG 12

Atrial rate: 220
Ventricular rate:
Rhythm: Atrial flutter with a single ventricular beat
P wave:
PR interval:
QRS complex:
  Axis:
  Duration:
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval:
U wave:
Diagnosis: Atrial flutter with a spectacularly inadequate ventricular escape rhythm

ECG 13

Atrial rate: 160
Ventricular rate: 160
Rhythm: AVNRT of the common or typical form
P wave:
PR interval:
QRS complex:
  Axis: −45°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 300 msec
U wave:
Diagnosis: AVNRT of the common or typical form with retrograde P waves visible after the QRS complexes in II, III, aVF, and V_1

ECG 14

Atrial rate: 290 in atrial flutter, and 75 in sinus rhythm
Ventricular rate: 145 in atrial flutter and 70 in sinus rhythm
Rhythm: Atrial flutter with 2:1 AV block converting to sinus rhythm
P wave: Normal in sinus rhythm
PR interval: 160 msec in sinus rhythm

QRS complex:
  Axis: 60°
  Duration: 90 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 360 msec
U wave:
Diagnosis: Atrial flutter with 2:1 block that converts to sinus rhythm

ECG 15

Atrial rate: 225
Ventricular rate: 75
Rhythm: Atrial flutter with 3:1 AV block
P wave:
PR interval:
QRS complex:
  Axis: −75°
  Duration: 160 msec, RBBB, LAFB
  Voltage: Normal
  Morphology: Tiny Q waves in V_1 and V_2
ST segment: Normal
T wave: Normal
QT interval: 400 msec
U wave:
Diagnosis: Atrial flutter with 3:1 AV block, left axis deviation, RBBB, left anterior fascicular block (axis ≥45°, small Q waves in aVL, and an IVCD), and tiny Q waves in V_1 and V_2 possibly indicating a previous septal MI. It is unusual to have atrial flutter with an odd ratio of atrial to ventricular rate.

ECG 16

Atrial rate: 220
Ventricular rate: 65
Rhythm: Atrial flutter with variable AV block
P wave:
PR interval:
QRS complex:
  Axis: −45°
  Duration: 160 msec, RBBB
  Voltage: Increased in aVL
  Morphology: Q waves in V_1 to V_3
ST segment: Elevated in V_2 to V_5
T wave: Nonspecific changes

QT interval: 420 msec
U wave:
Diagnosis: Atrial flutter with variable AV block, left axis deviation, RBBB, anterior MI age undetermined, and LVH by voltage criteria in aVL

ECG 17

Atrial rate: 300
Ventricular rate: 95
Rhythm: Atrial flutter with variable AV block
P wave:
PR interval:
QRS complex:
  Axis:
  Duration: 80 msec
  Voltage: Low voltage
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 360 msec
U wave:
Diagnosis: Atrial flutter with variable AV block and low voltage. The flutter waves are not as obvious in this tracing.

ECG 18

Atrial rate: 230
Ventricular rate: 115
Rhythm: Atrial flutter with 2:1 AV block
P wave:
PR interval:
QRS complex:
  Axis: Indeterminate
  Duration: 80 msec
  Voltage: Low voltage
  Morphology: Small Q waves in II, III, and aVF
ST segment: Normal
T wave: Normal
QT interval: 300 msec
U wave:
Diagnosis: Atrial flutter with 2:1 AV block and low voltage

ECG 19

Atrial rate: 288
Ventricular rate: 72
Rhythm: Atrial flutter with 4:1 AV block
P wave:
PR interval:
QRS complex:
Axis: 15°
Duration: 80 msec
Voltage: Normal
Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 380 msec
U wave:
Diagnosis: Atrial flutter with 4:1 AV block

ECG 20

Atrial rate: 310
Ventricular rate: 155
Rhythm: Atrial flutter with 2:1 AV block
P wave:
PR interval:
QRS complex:
Axis: −45°
Duration: 90 msec
Voltage: Increased in the precordial leads and aVL
Morphology: Normal
ST segment: Nonspecific changes
T wave: Normal
QT interval: 260 msec
U wave:
Diagnosis: Atrial flutter with 2:1 AV block, left axis deviation, and LVH by voltage criteria in the precordial leads and aVL

Day 6

Ectopic Arrhythmias and Triggered Activity

I. Ectopy—a disorder of impulse formation

A. Mechanisms of ectopic arrhythmias

1. Ectopic arrhythmias require:
    a. Default—slowing of the normal dominant sinus pacemaker which allows a slower focus to take control, or
    b. Usurpation—an acceleration of a lower pacemaker which takes control by virtue of being faster than the sinus rate
2. Disorders of the sinus node, such as SA arrest, SA exit block, or excessive vagal tone may allow a lower focus to take control by default
3. A variety of factors, including digitalis toxicity, hypoxia, electrolyte disturbances, ischemia, or chronic lung disease may stimulate an ectopic focus to accelerate and usurp control from the SA node

B. Properties of ectopic arrhythmias

1. Ectopic arrhythmias usually start and stop gradually (*non-paroxysmally*)
2. They are not usually initiated by a premature beat
3. They may be somewhat irregular
4. They are not terminated by vagal maneuvers, although AV block may be increased
5. AV block of varying degrees is frequently present (particularly if digitalis toxicity is the cause)
6. These arrhythmias are usually quite resistant to treatment with standard class I or III agents
7. Catheter ablation may be effective if a causative agent cannot be identified or treated

II. The major ectopic arrhythmias

A. Wandering atrial pacemaker

1. Mechanisms and causes
    a. There are three or more ectopic atrial pacemakers
    b. This arrhythmia is typically seen in young healthy persons, particularly athletes
    c. The etiology is uncertain

2. Heart rate—the heart rate is 60-100 and is usually irregular
3. ECG morphology (Day 6-01)
    a. There are at least three P wave morphologies with varying PR intervals
    b. There is usually moderate variation in the heart rate

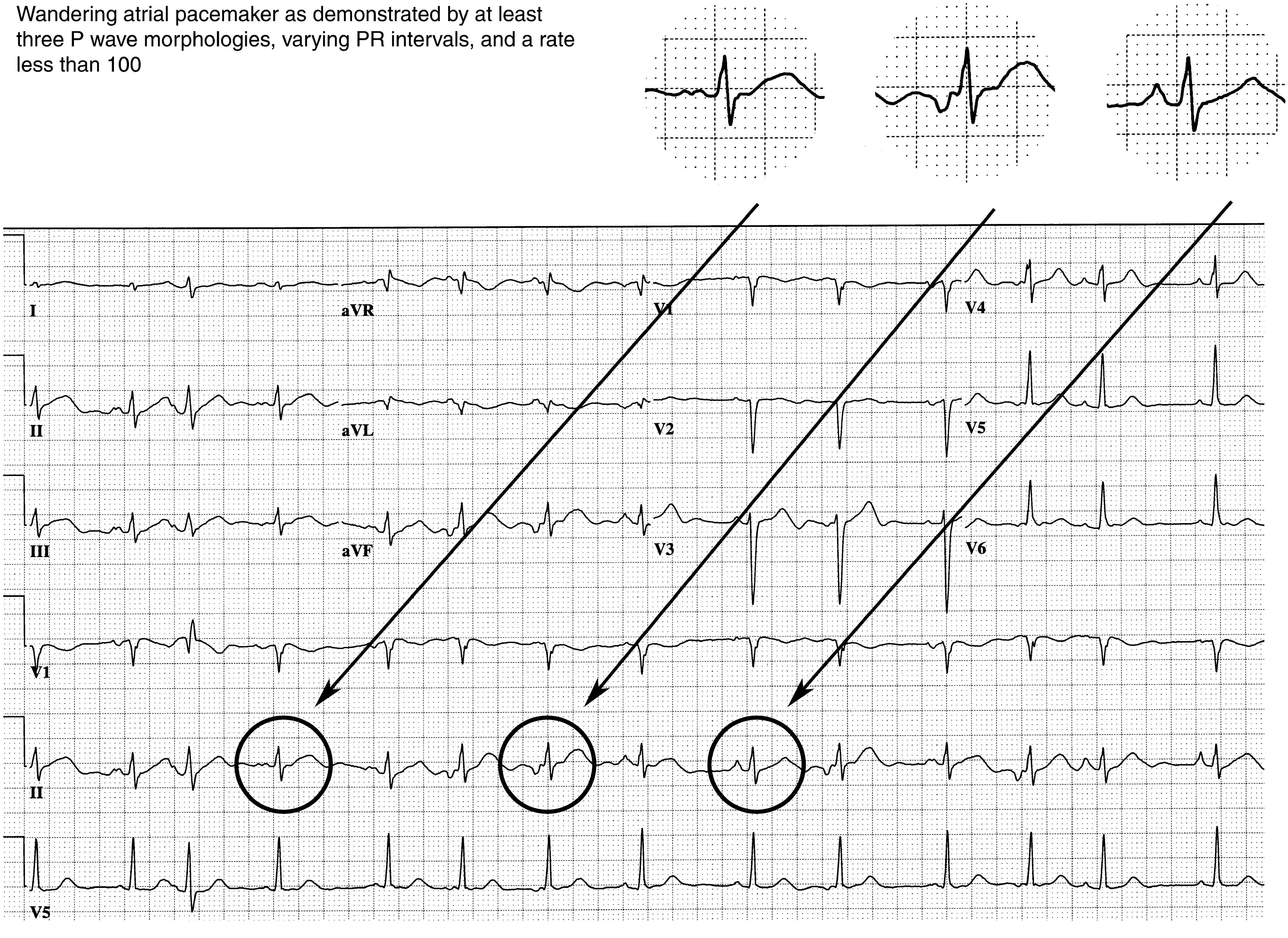
B. Multifocal atrial tachycardia
1. Mechanisms and causes
    a. Caused by multiple ectopic atrial foci
    b. Chronic lung disease is typically the underlying clinical abnormality, although it can also occur in the setting of hypoxia, electrolyte abnormalities, acid-base disturbances, and ischemia (i.e., frequently in the intensive care setting)
2. ECG morphology (Day 6-02)
    a. There are at least three P wave morphologies with varying PR intervals
    b. The rate is 100-140
    c. There is typically 1:1 AV conduction
    d. This arrhythmia is frequently confused with atrial fibrillation; the distinction is an important one since management is usually very different

C. Ectopic atrial rhythms
1. Mechanisms and causes
    a. A single ectopic atrial focus accelerates and usurps control from the sinus node, or the sinus node slows down and allows an ectopic focus to appear
    b. Digitalis toxicity, electrolyte abnormalities, ischemia, hypoxia, and chronic lung disease are typical causes
2. ECG morphology (Day 6-03) (Day 6-04)
    a. The P waves are of the same morphology but have an abnormal axis, indicating their ectopic origin
    b. The atrial rate may be slightly irregular
    c. AV block of varying degrees is sometimes present (particularly if digitalis toxicity is the cause)
    d. Atrial tachycardia with AV block should be considered a manifestation of digitalis toxicity until proven otherwise (Day 6-05)
    e. The atrial rate in atrial tachycardia is usually 140-200
    f. Atrial tachycardia may be confused with atrial flutter, but the latter is usually faster and has the typical saw tooth pattern

D. Ectopic junctional rhythms
1. Mechanisms and causes
    a. A single focus near the AV node accelerates and usurps control from the sinus node
    b. Digitalis toxicity, electrolyte abnormalities, ischemia, hypoxia, and chronic lung disease are typical causes
2. ECG morphology (Day 6-06)

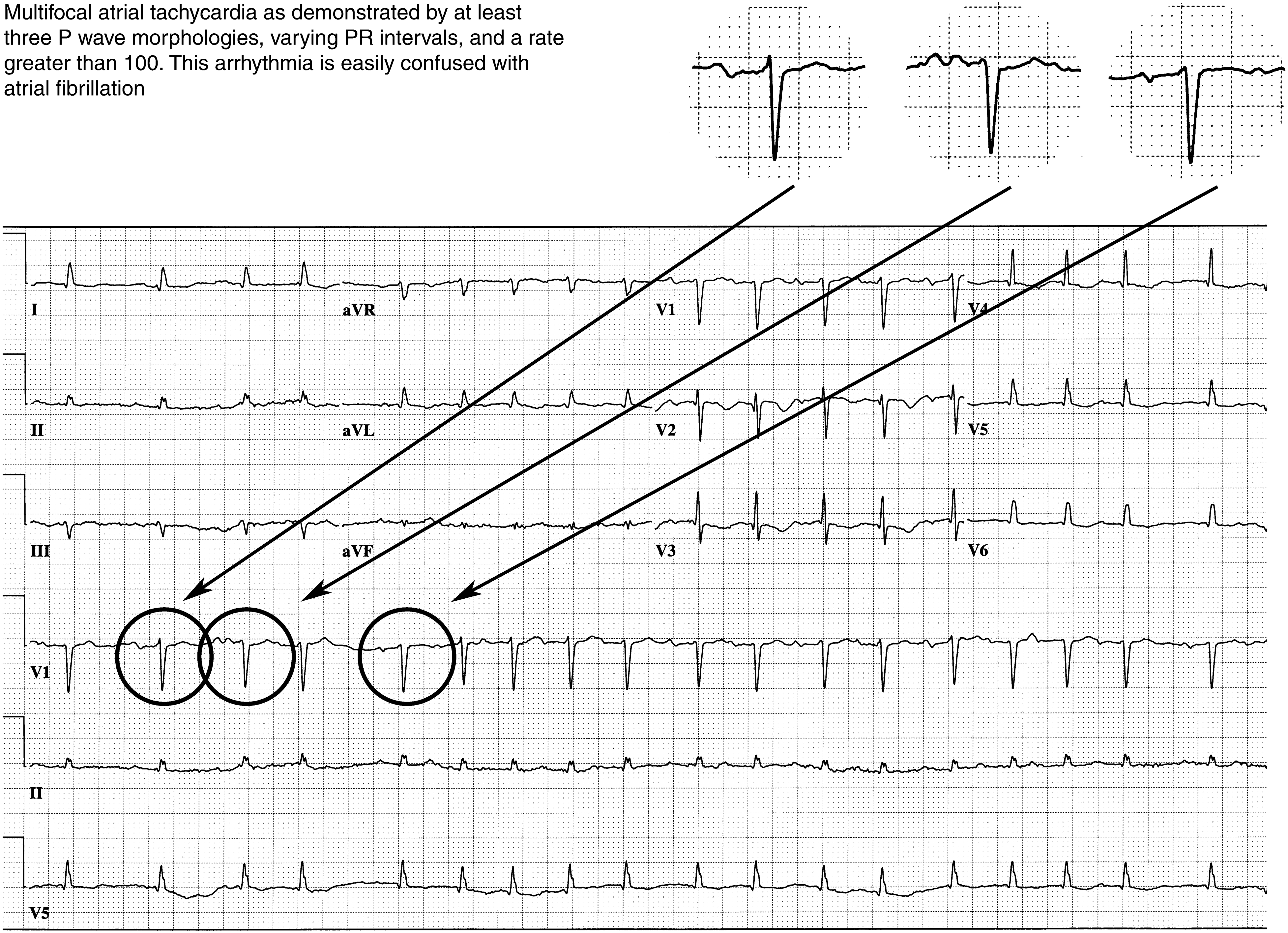
DAY 6-01

Wandering atrial pacemaker as demonstrated by at least three P wave morphologies, varying PR intervals, and a rate less than 100



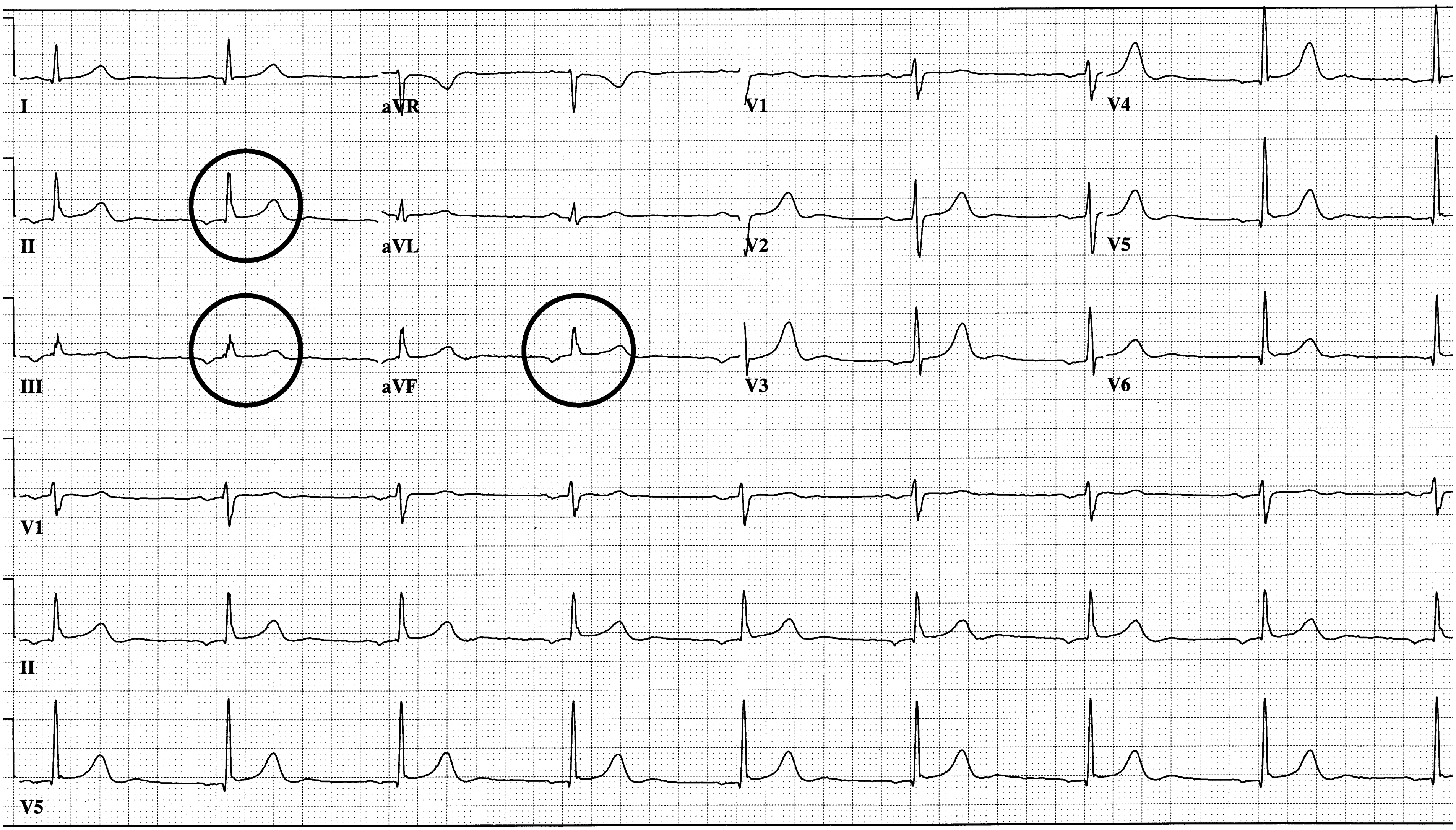
DAY 6-02

Multifocal atrial tachycardia as demonstrated by at least three P wave morphologies, varying PR intervals, and a rate greater than 100. This arrhythmia is easily confused with atrial fibrillation



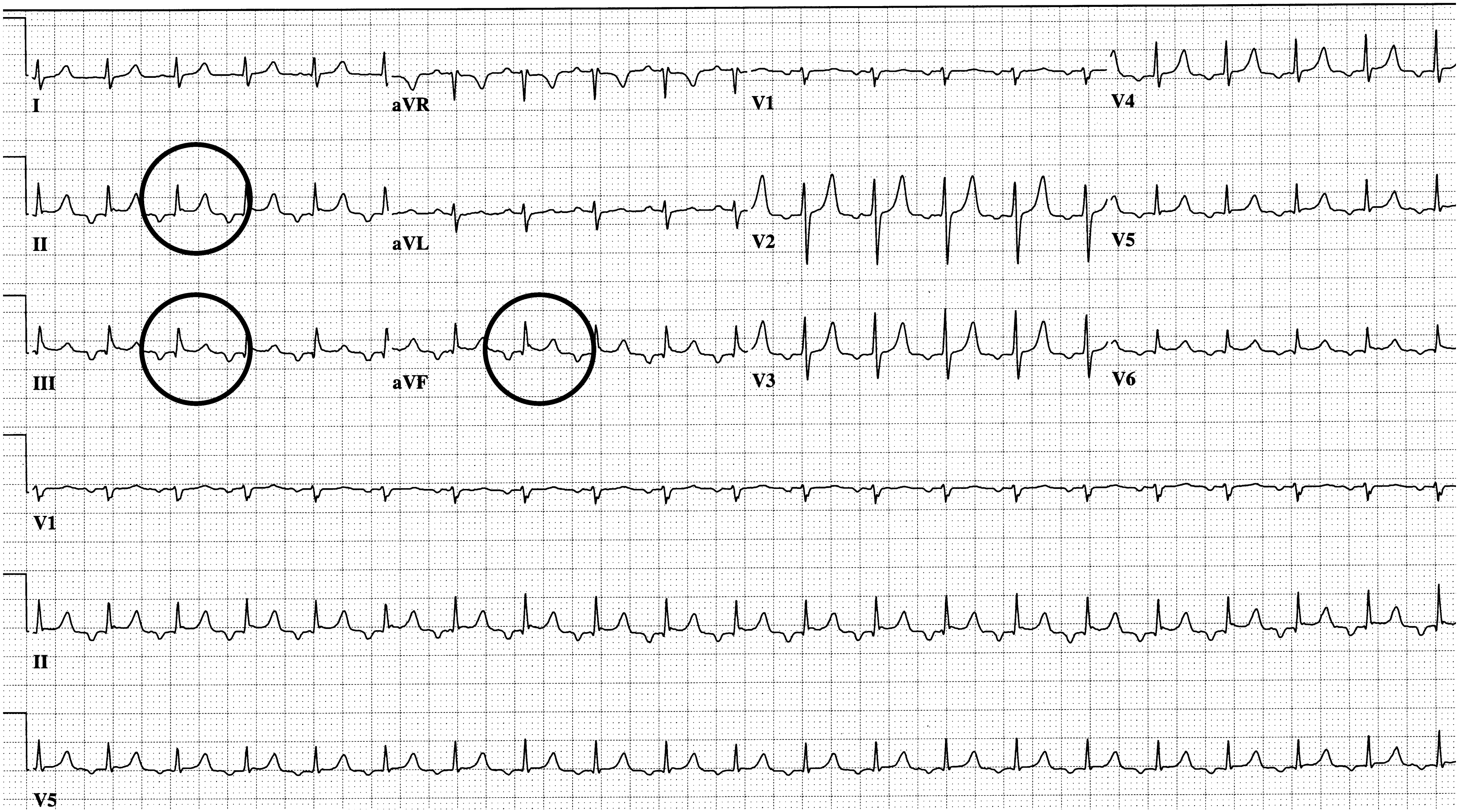
DAY 6-03

Ectopic atrial bradycardia as indicated by inverted P waves in the inferior leads and a heart rate less than 60



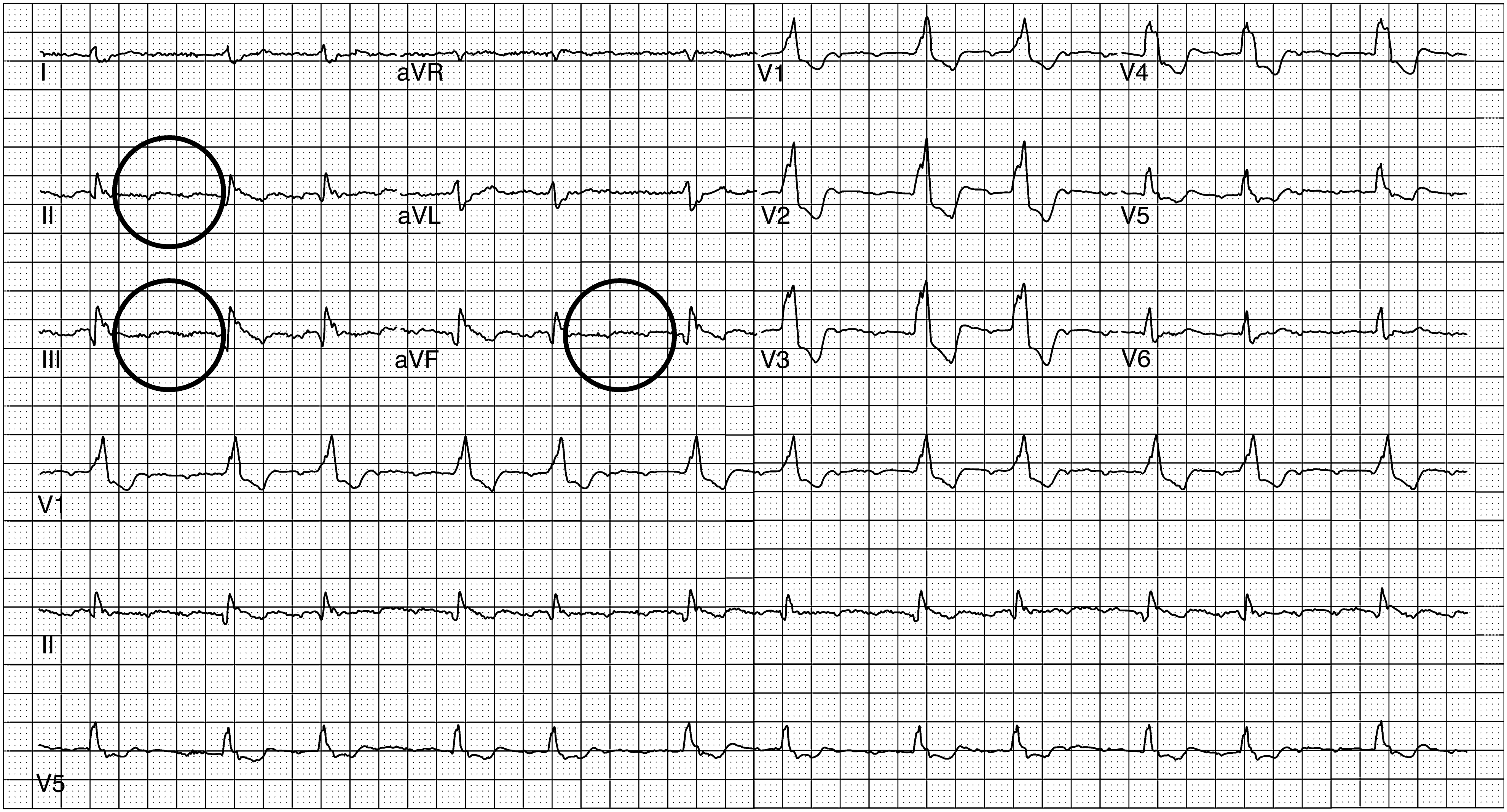
DAY 6-04

Ectopic atrial tachycardia as demonstrated by inverted P waves in the inferior leads and a rate greater than 100



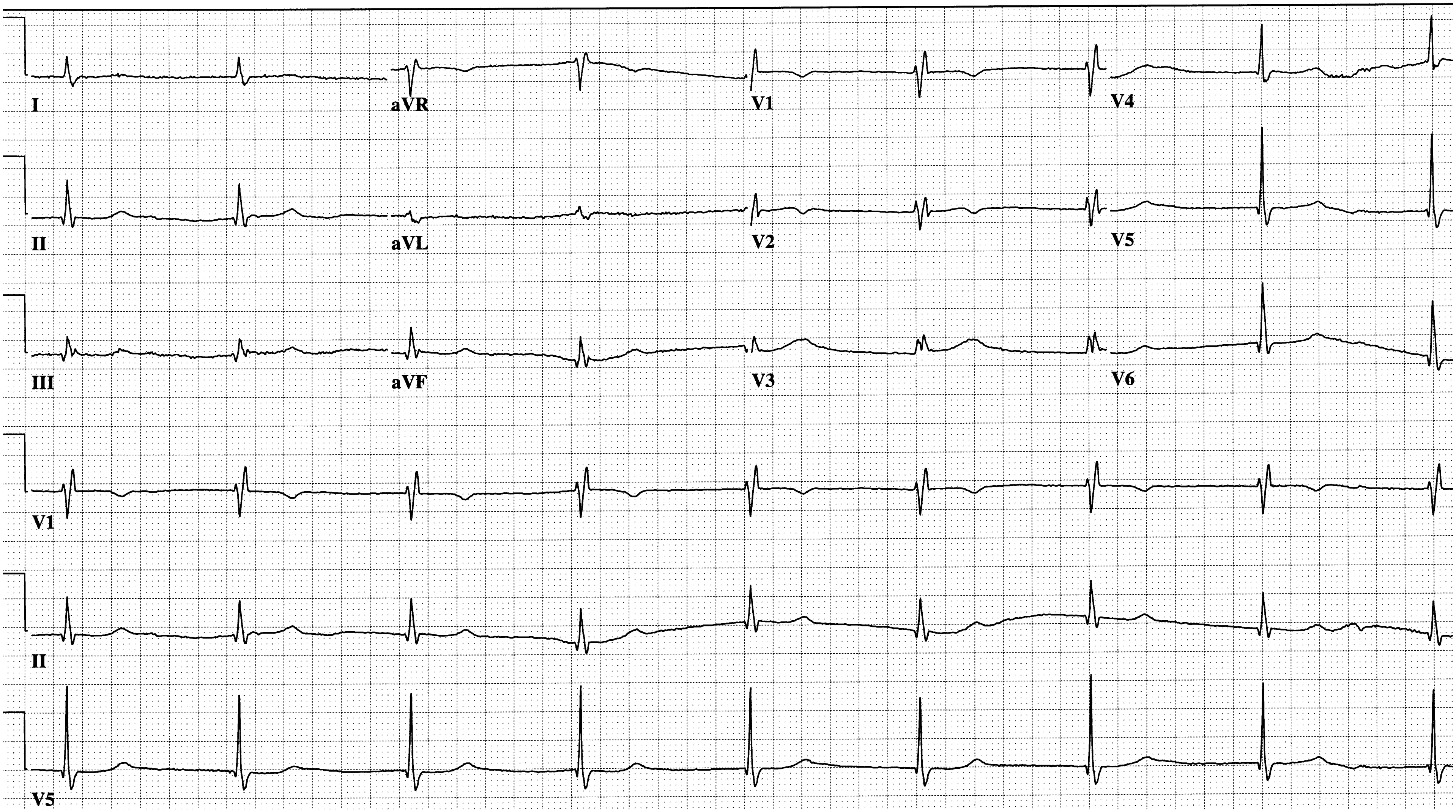
DAY 6-05

Atrial tachycardia with variable AV block as demonstrated by inverted P waves in the inferior leads.
The patients serum digoxin level was 3.76 ng/l



DAY 6-06

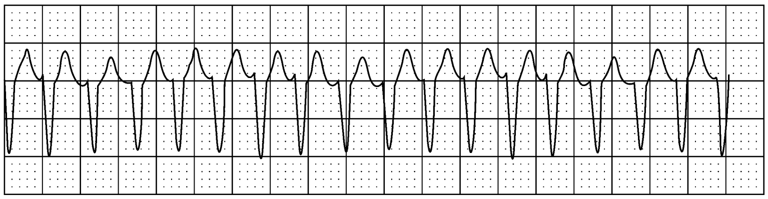
Junctional rhythm as evidenced by the lack of P waves



a. If P waves are visible, they demonstrate an abnormal axis and appear slightly before or after the QRS complex
b. Junctional tachycardia (rate >60), or accelerated junctional rhythm, should be considered a manifestation of digitalis toxicity until proven otherwise (Day 6-07) (Day 6-08)
c. Junctional tachycardia may be confused with atrial tachycardia, but the latter has a normal PR interval (>120 msec)

E. Ectopic ventricular rhythms
1. Mechanisms and causes
a. A single focus in the right or left ventricle, usually near the His-Purkinje fibers, accelerates and usurps control from the sinus node
b. Ischemia, a scar from a previous MI, electrolyte abnormalities, and dilated cardiomyopathy are typical causes
c. VT can also be associated with right ventricular dysplasia, a congenital condition effecting the right ventricular free wall and/or RV outflow tract (this abnormality may also produce reentrant VT)
2. ECG morphology
a. The ECG demonstrates a wide QRS tachycardia
b. There may be AV dissociation
c. In RV dysplasia, the ECG shows LBBB, right axis deviation, and T wave inversion over the right precordium
F. Summary of ectopic arrhythmias

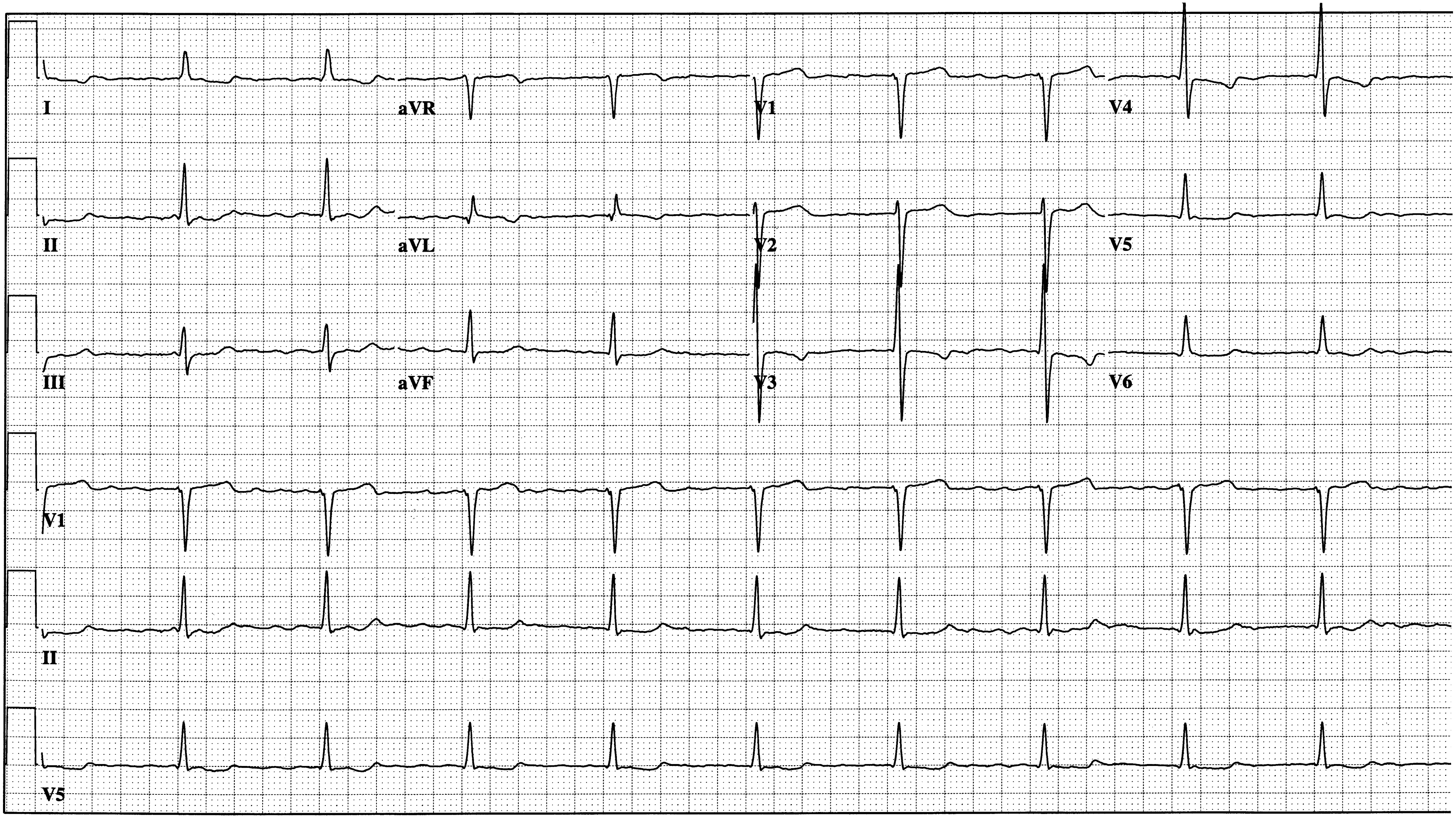
Lead V_1 - ectopic ventricular tachycardia in a 23 year old woman, subsequently treated by radiofrequency catheter ablation



Summary of ectopic arrhythmias

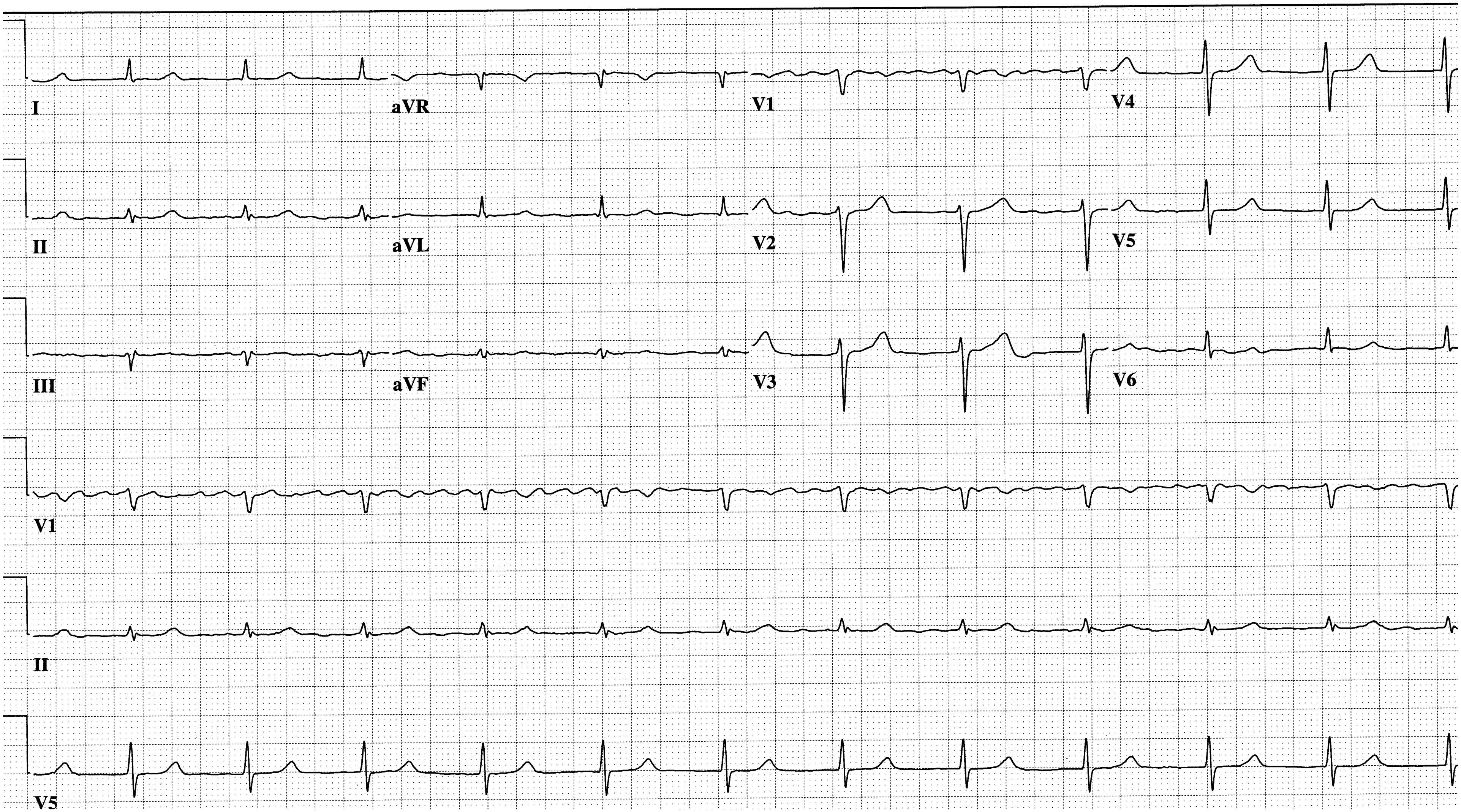
ARRHYTHMIA	ECTOPIC RATE	ECG DESCRIPTION
Wandering Atrial Pacemaker	60–100	Multiple P wave morphologies (usually 3 or more), variable rate
Ectopic Atrial Rhythm	40–250	Regular P waves with abnormal axis, PR interval > 120 msec, flat baseline between P waves, AV conduction may be 1:1 or variable
Mulitifocal Atrial Tachycardia	100–180	At least 3 P wave morphologies, varying PR intervals, rate > 100
Junctional Rhythms	40–120	Regular ventricular rhythm with P waves slightly before, hidden inside, or after QRS complex, PR interval < 120 msec
VT	120–250	Wide QRS tachycardia, regular ventricular rate

DAY 6-07



DAY 6-08

Atrial fibrillation with complete heart block and accelerated junctional rhythm. There is an irregular baseline consistent with atrial fibrillation, but the ventricular response is regular indicating a junctional escape rhythm. The junctional rate is about 70. All of this is highly suggestive of digoxin toxicity



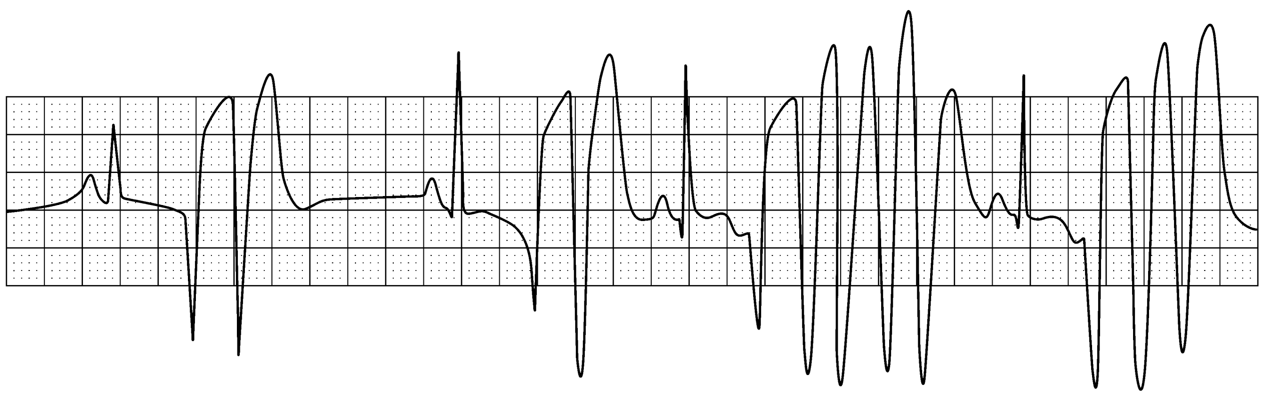
III. Triggered activity

A. Mechanisms of triggered activity

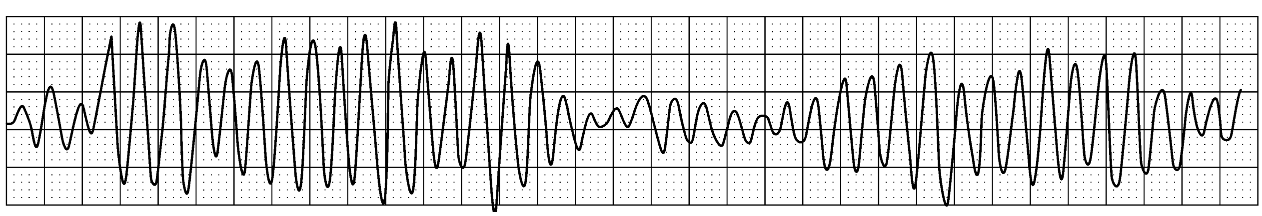
1. Triggered activity is initiated in conducting tissue by *afterdepolarizations*
2. Afterdepolarizations are oscillations of membrane voltage induced by one or more preceding action potentials
3. If the afterdepolarization voltage reaches the membrane threshold potential, a sustained arrhythmia may result
4. Patients with the congenital long QT syndromes or those treated with class I or class III antiarrhythmic agents (e.g. quinidine, procainamide, sotalol), erythromycin, or other drugs some are at increased risk for triggered activity arrhythmias
5. Triggered activity arrhythmias are exacerbated by hypokalemia or hypomagnesemia

B. Properties of triggered activity arrhythmias

1. Sustained, rapid ventricular tachycardia may be caused by triggered activity
2. Another from of VT, torsade de pointes, is a subset of *polymorphic ventricular tachycardia*, and is characterized by a rapid, irregular ventricular rate and a cyclically changing morphology
3. The treatment of these arrhythmias usually involves treatment of the underlying cardiac disease, correction of an electrolyte abnormality, or cessation of an offending drug
4. Some of these arrhythmias respond to verapamil, ventricular pacing, or beta agonists



Sinus rhythm with multiform PVCs which degenerates in the next panel to *torsade de pointes*



Sample Tracings
ECG 1

Atrial rate: ______________________

Ventricular rate: __________________

Rhythm: _________________________

P wave: _________________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ___________________

Voltage: ____________________

Morphology: _________________

ST segment: _________________

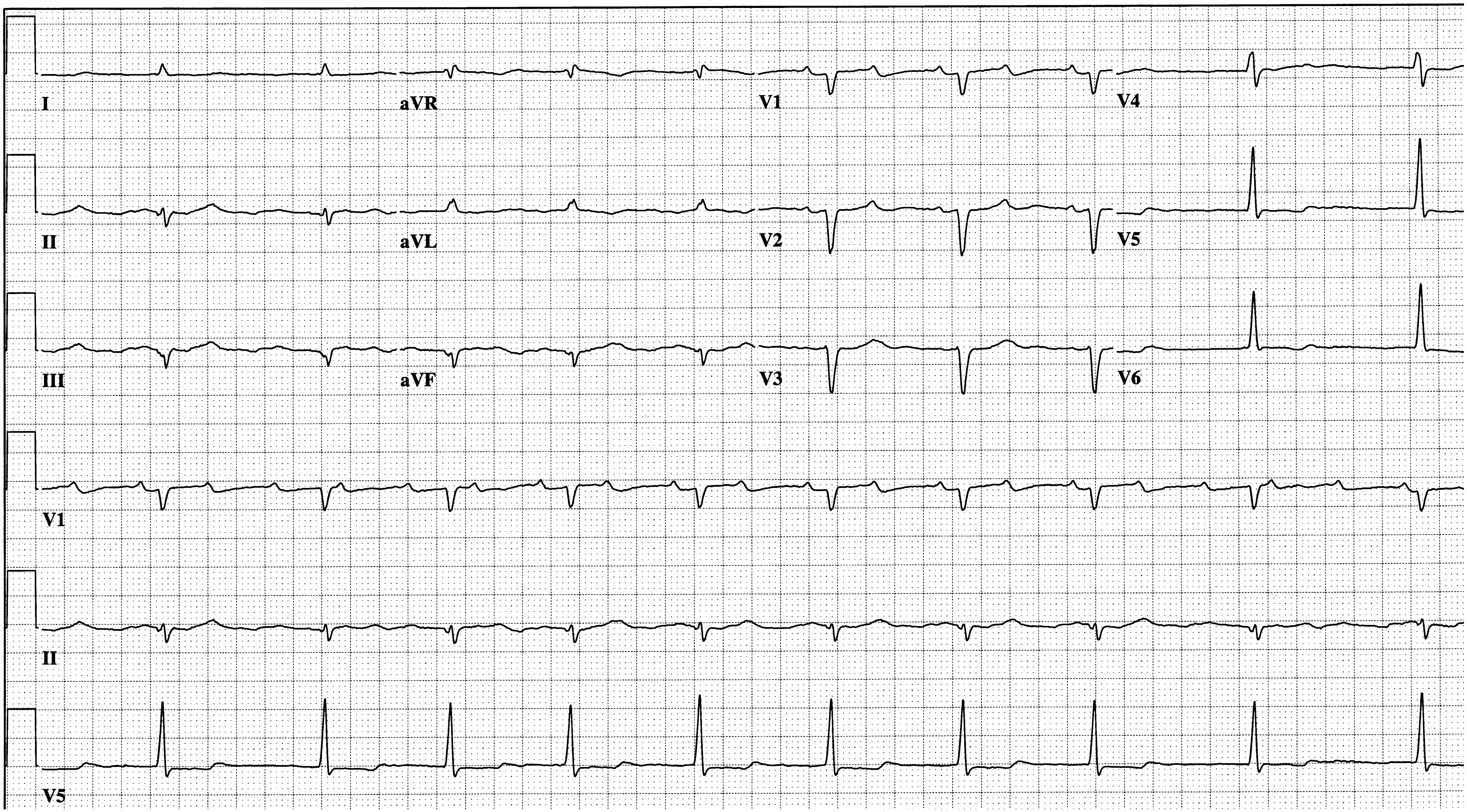
T wave: _____________________

QT interval: _________________

U wave: _____________________

Diagnosis: ___________________

____



ECG 2

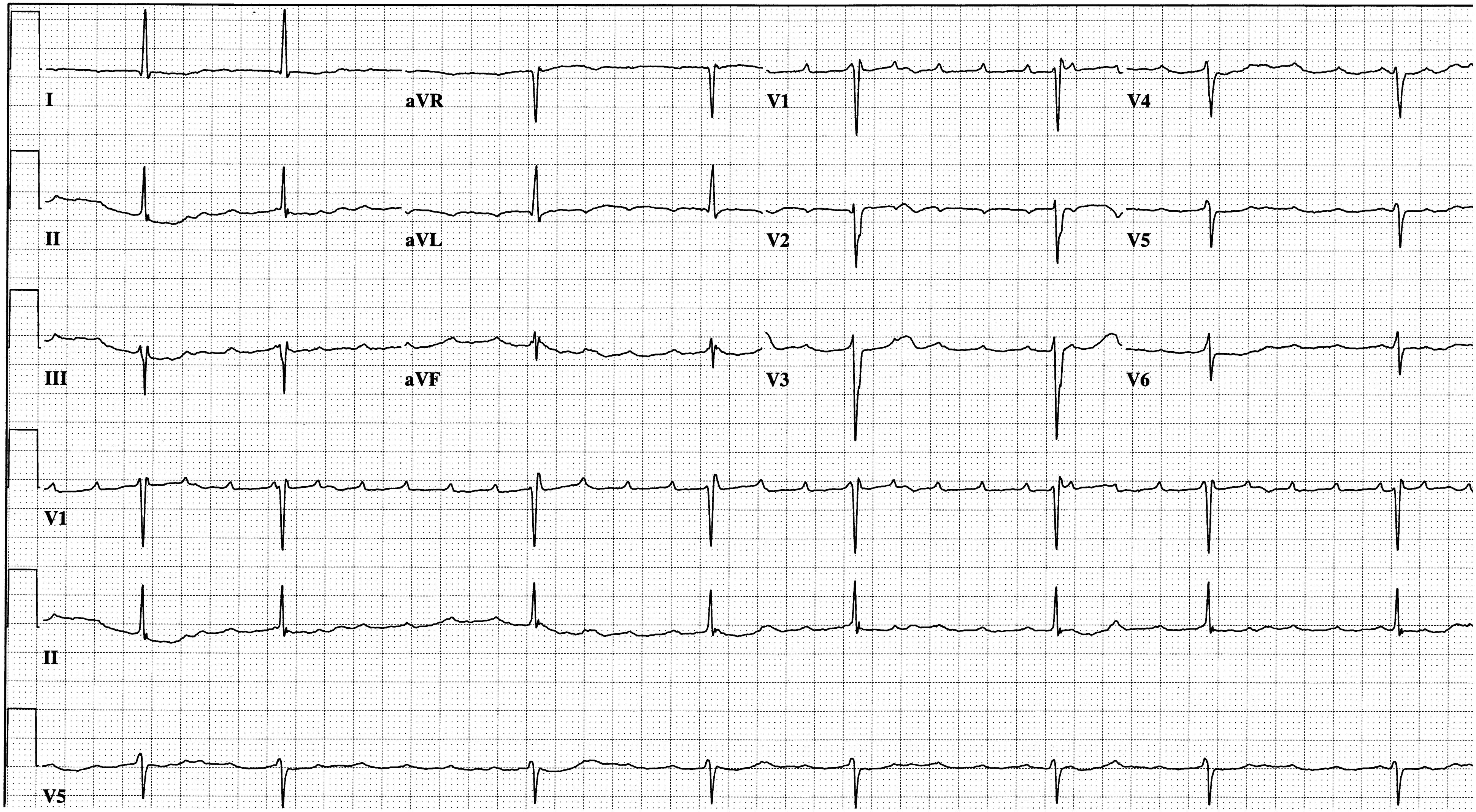
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG 3

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

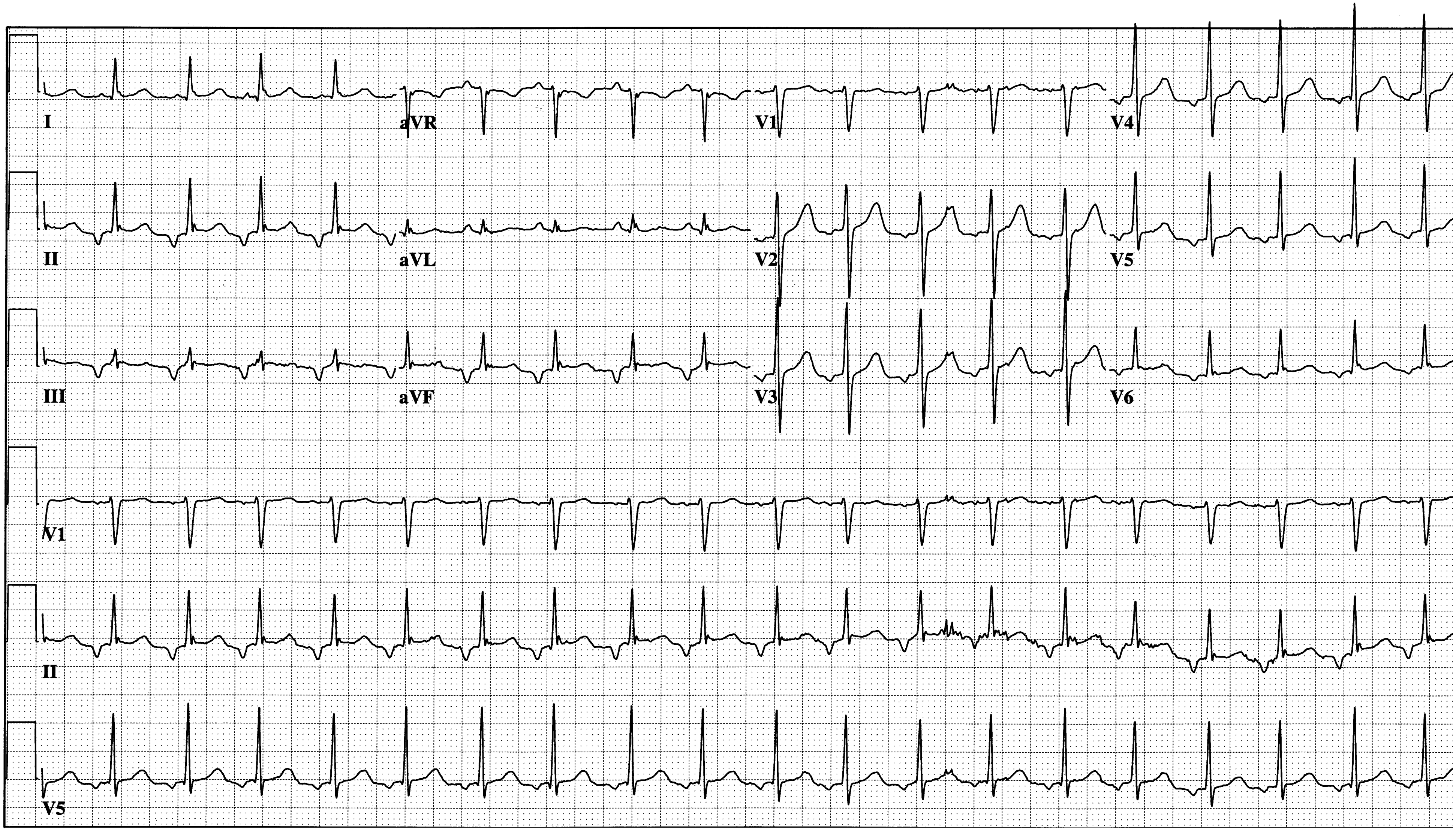
ST segment: ______

T wave: ______

QT interval: ______

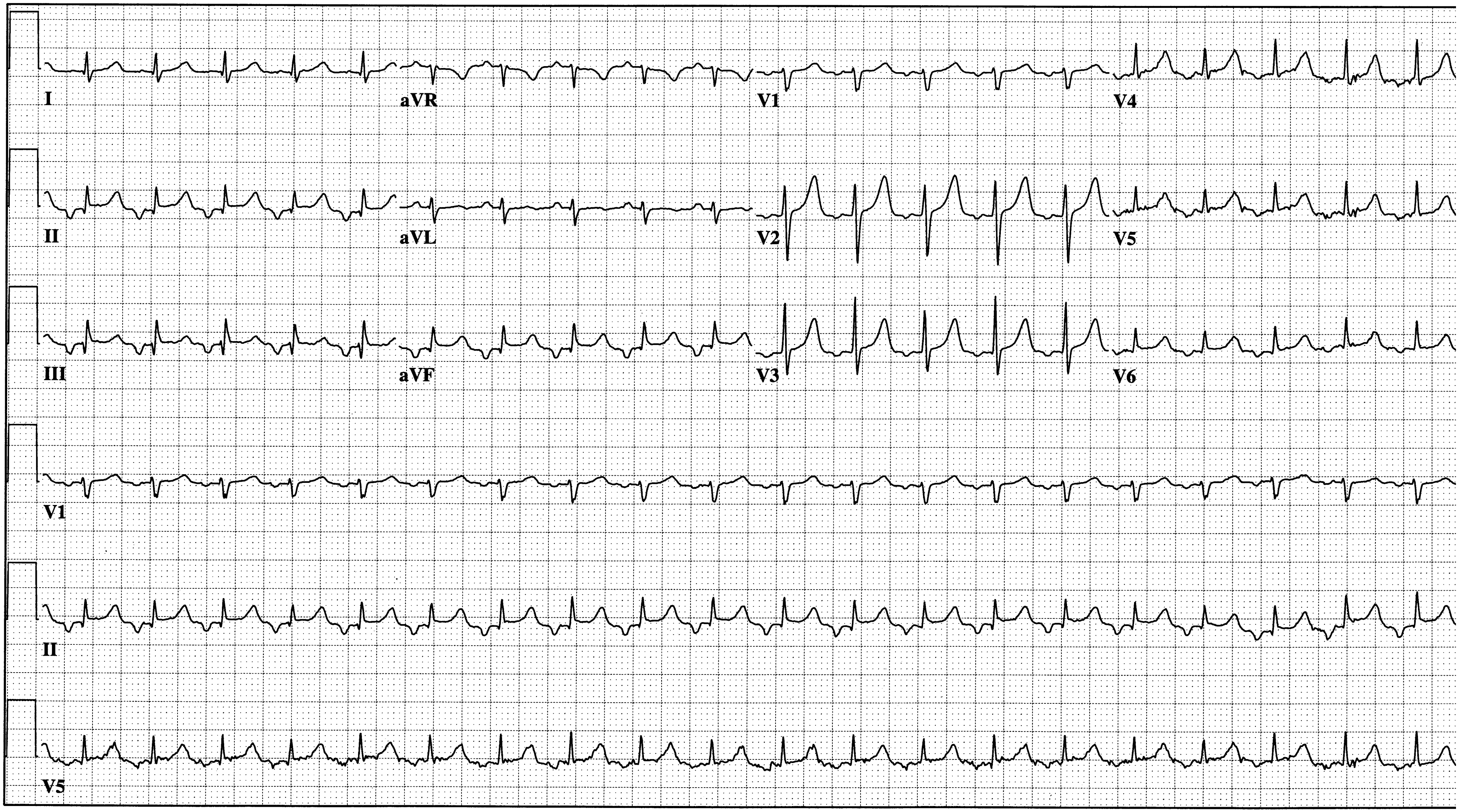
U wave: ______

Diagnosis: ______



ECG 4

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG 5

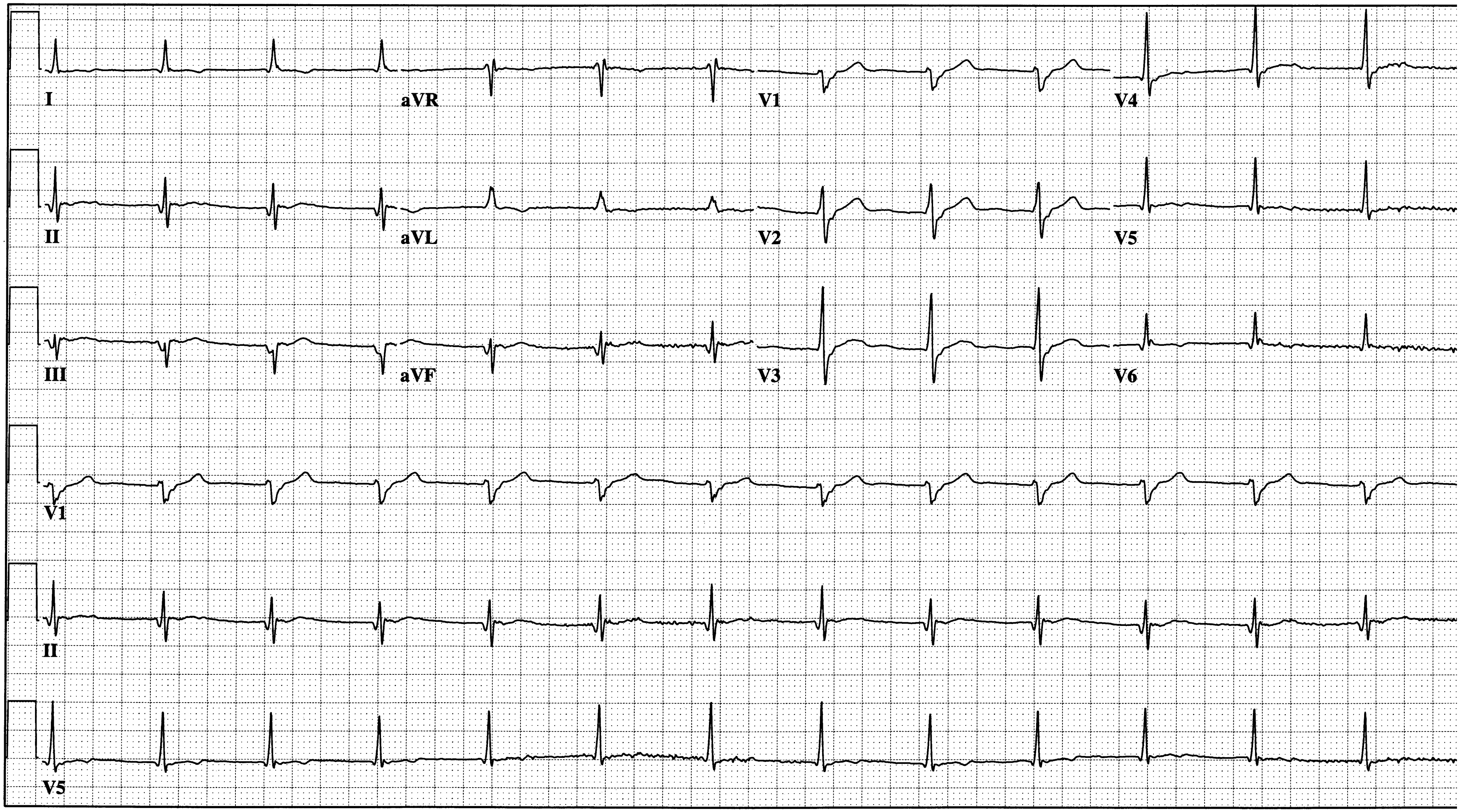
Atrial rate: ____________ QRS complex: ST segment: ____________

Ventricular rate: ____________ Axis: ____________ T wave: ____________

Rhythm: ____________ Duration: ____________ QT interval: ____________

P wave: ____________ Voltage: ____________ U wave: ____________

PR interval: ____________ Morphology: ____________ Diagnosis: ____________



ECG 6

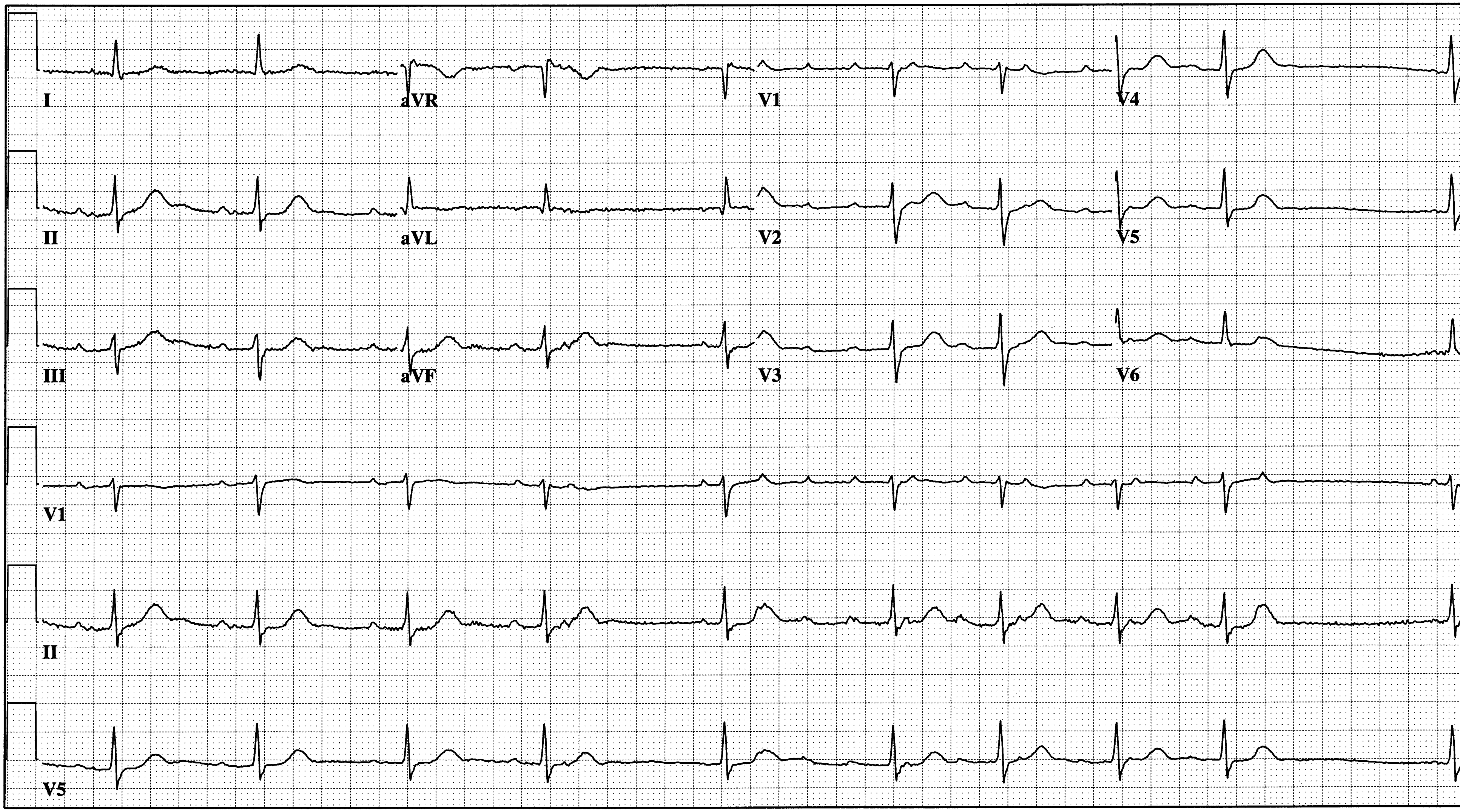
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

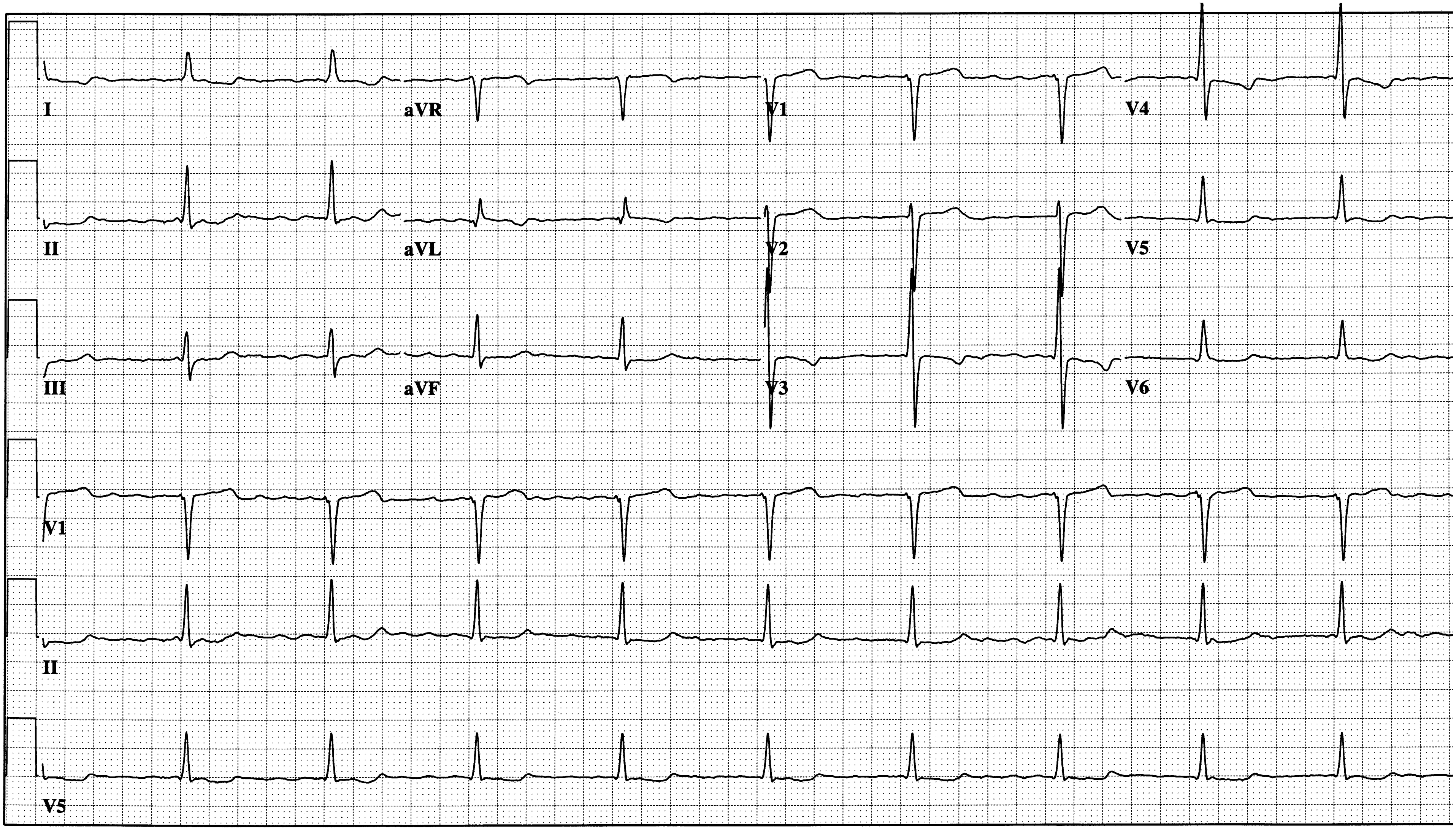
Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG 7



ECG 8

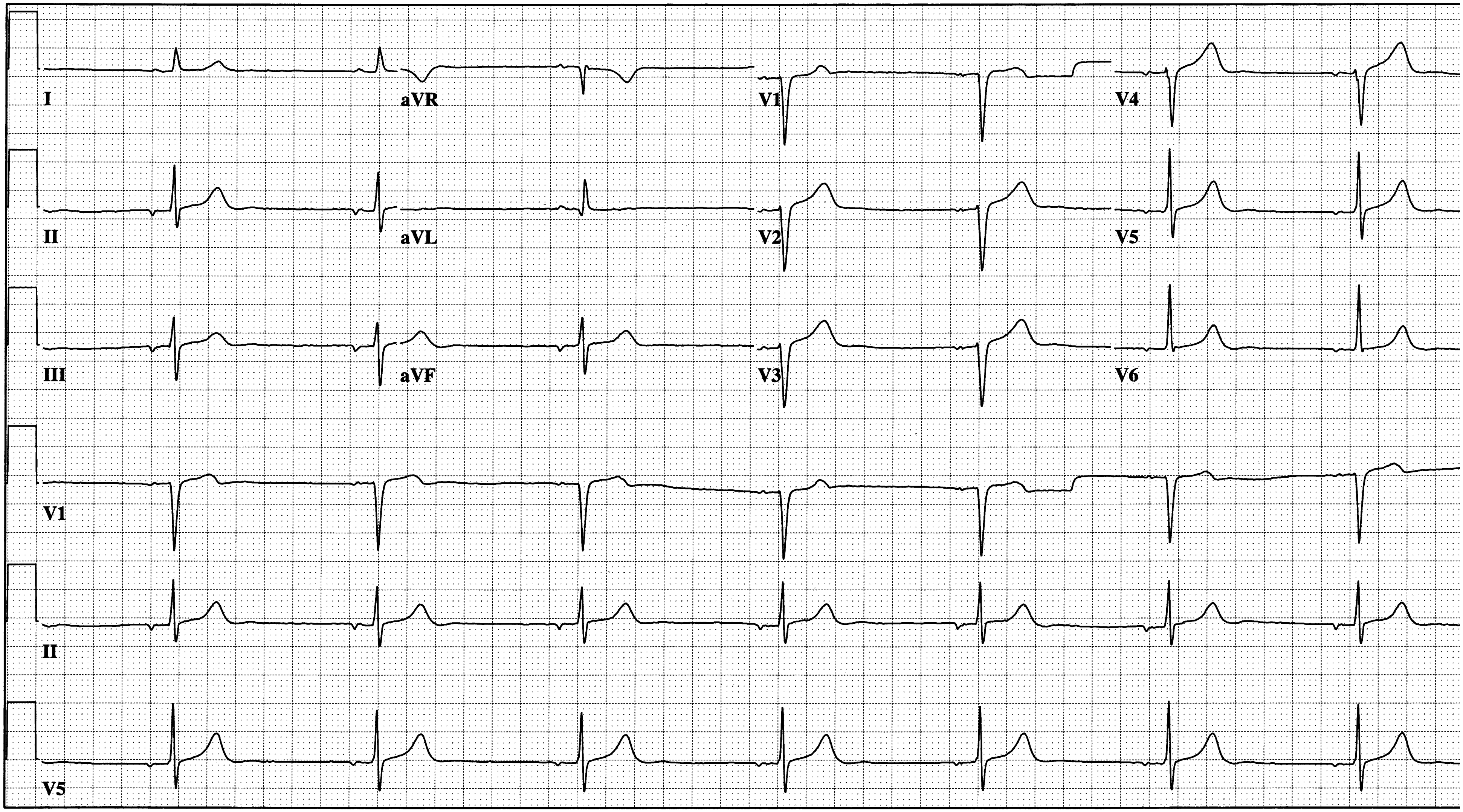
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG 9

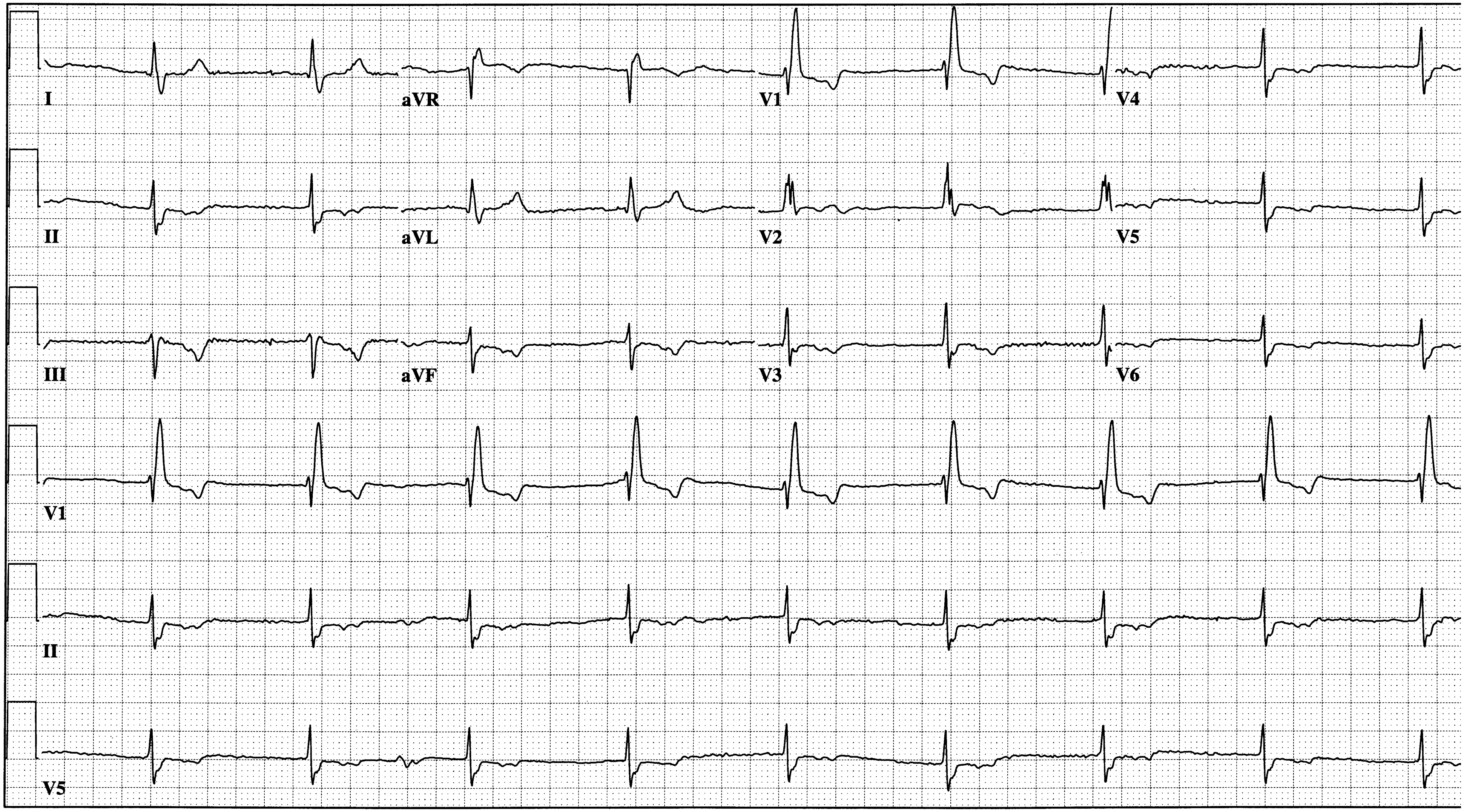
Atrial rate: ______________ QRS complex: ST segment: ______________

Ventricular rate: ______________ Axis: ______________ T wave: ______________

Rhythm: ______________ Duration: ______________ QT interval: ______________

P wave: ______________ Voltage: ______________ U wave: ______________

PR interval: ______________ Morphology: ______________ Diagnosis: ______________



ECG 10

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

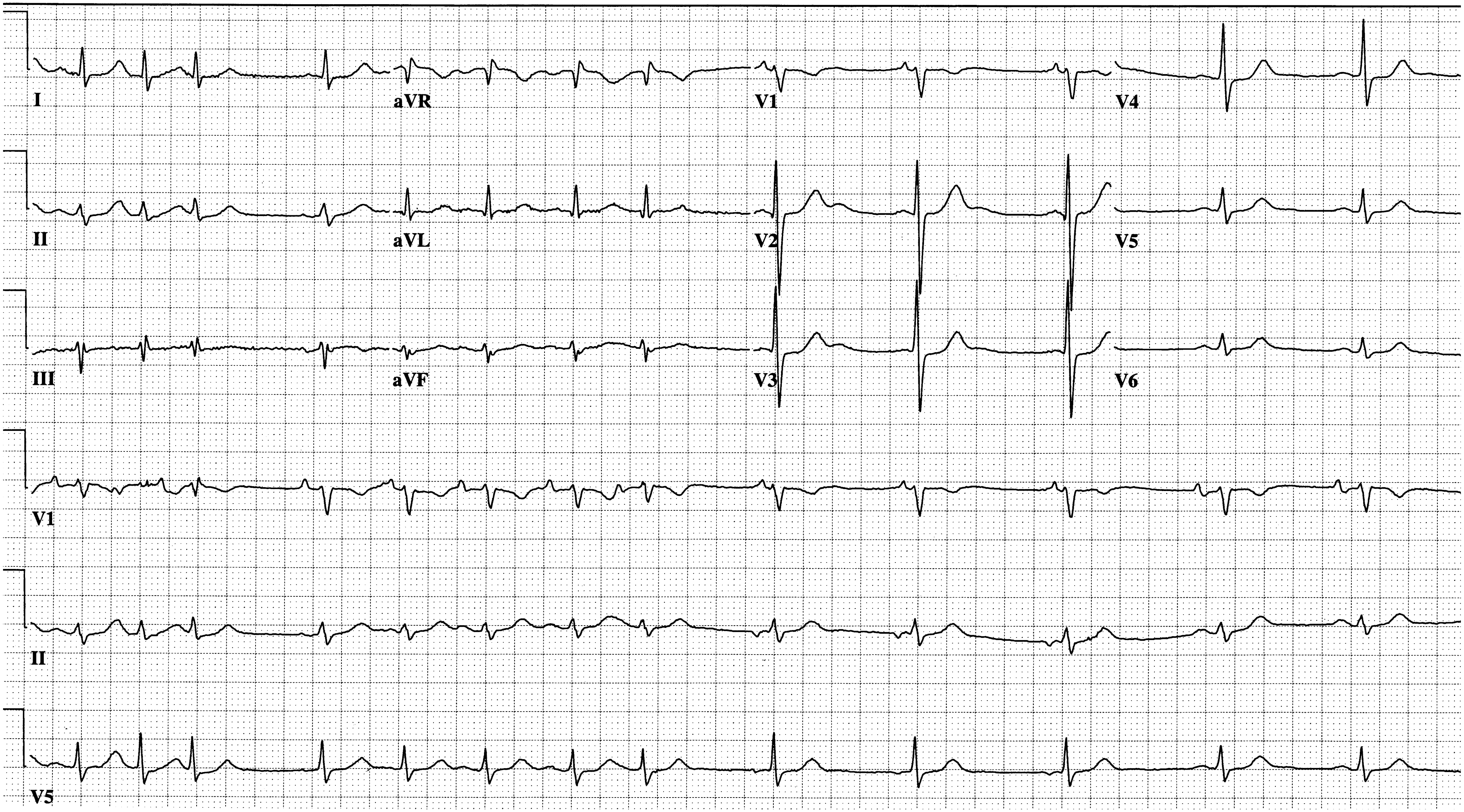
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG 11

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

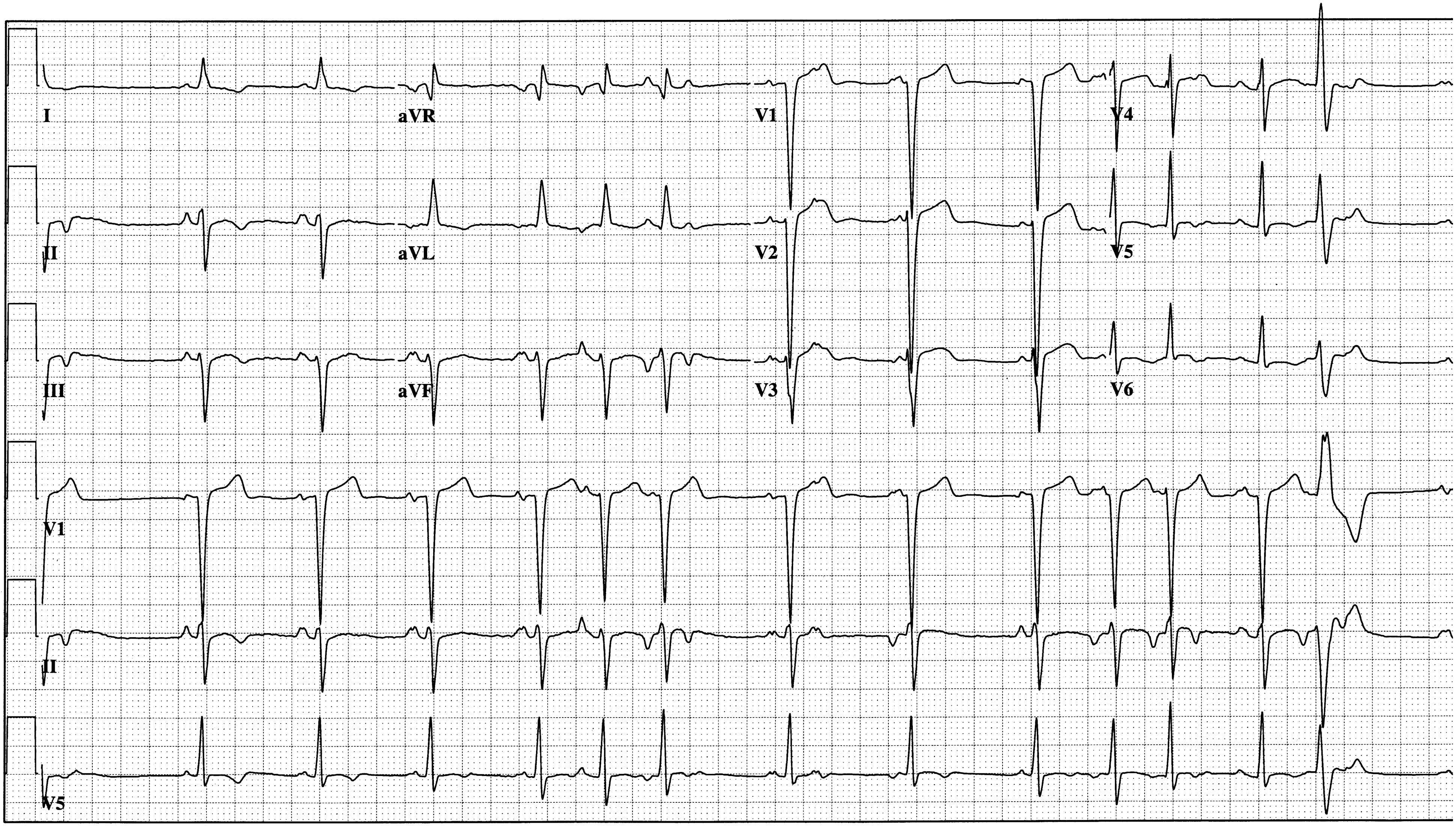
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG 12

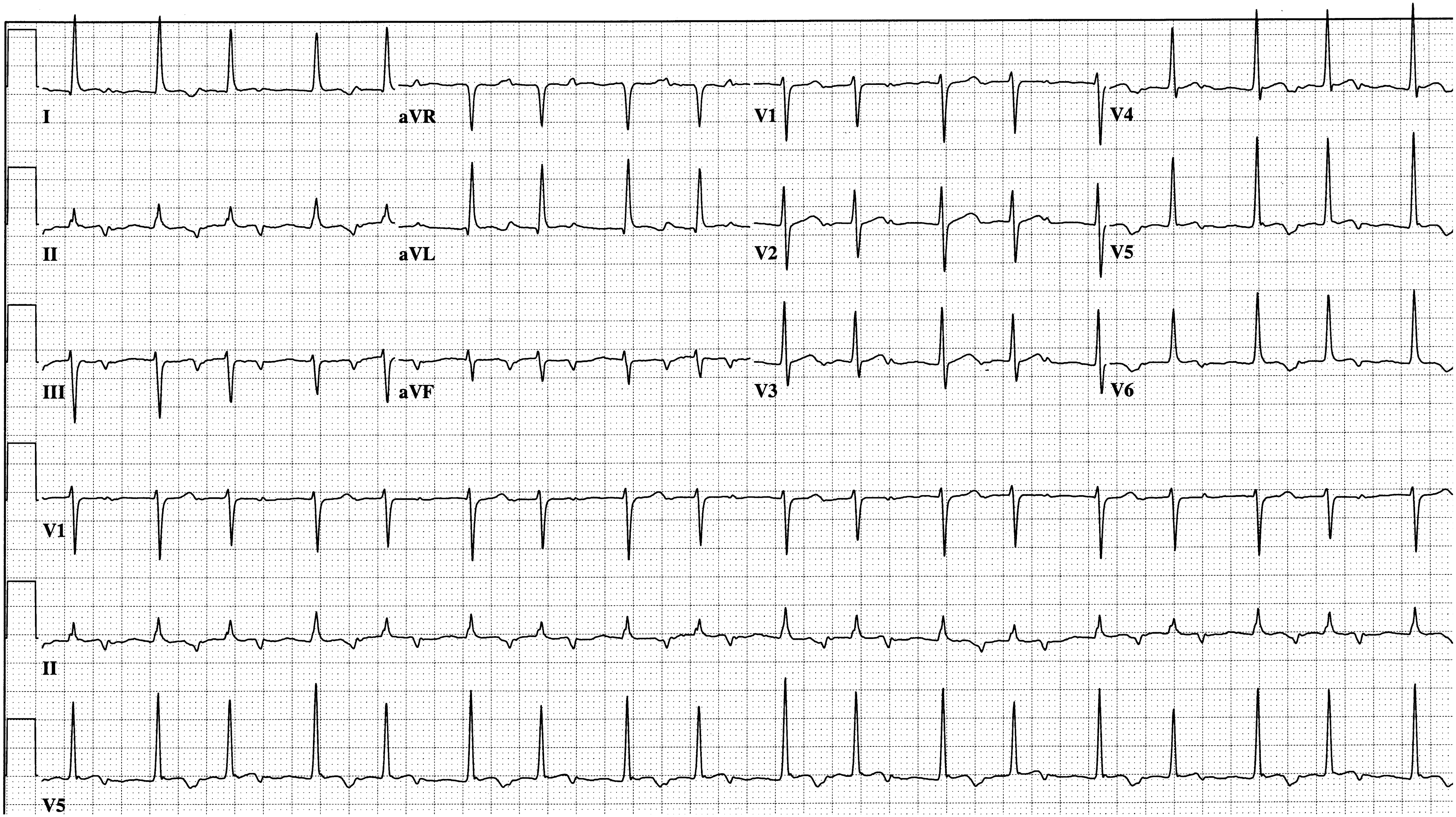
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG 13

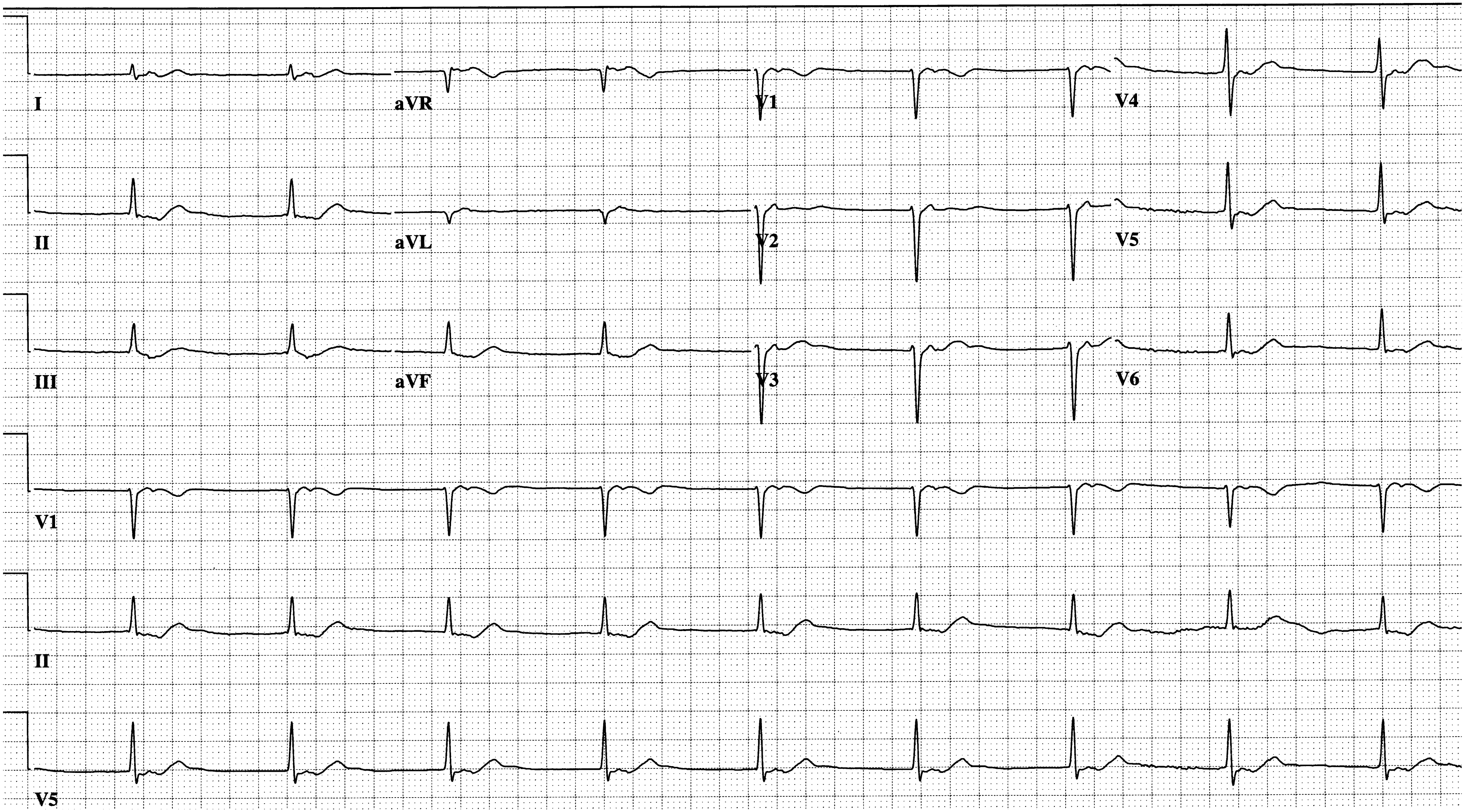
Atrial rate: ____________ QRS complex: ST segment: ____________

Ventricular rate: ____________ Axis: ____________ T wave: ____________

Rhythm: ____________ Duration: ____________ QT interval: ____________

P wave: ____________ Voltage: ____________ U wave: ____________

PR interval: ____________ Morphology: ____________ Diagnosis: ____________



ECG 14

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

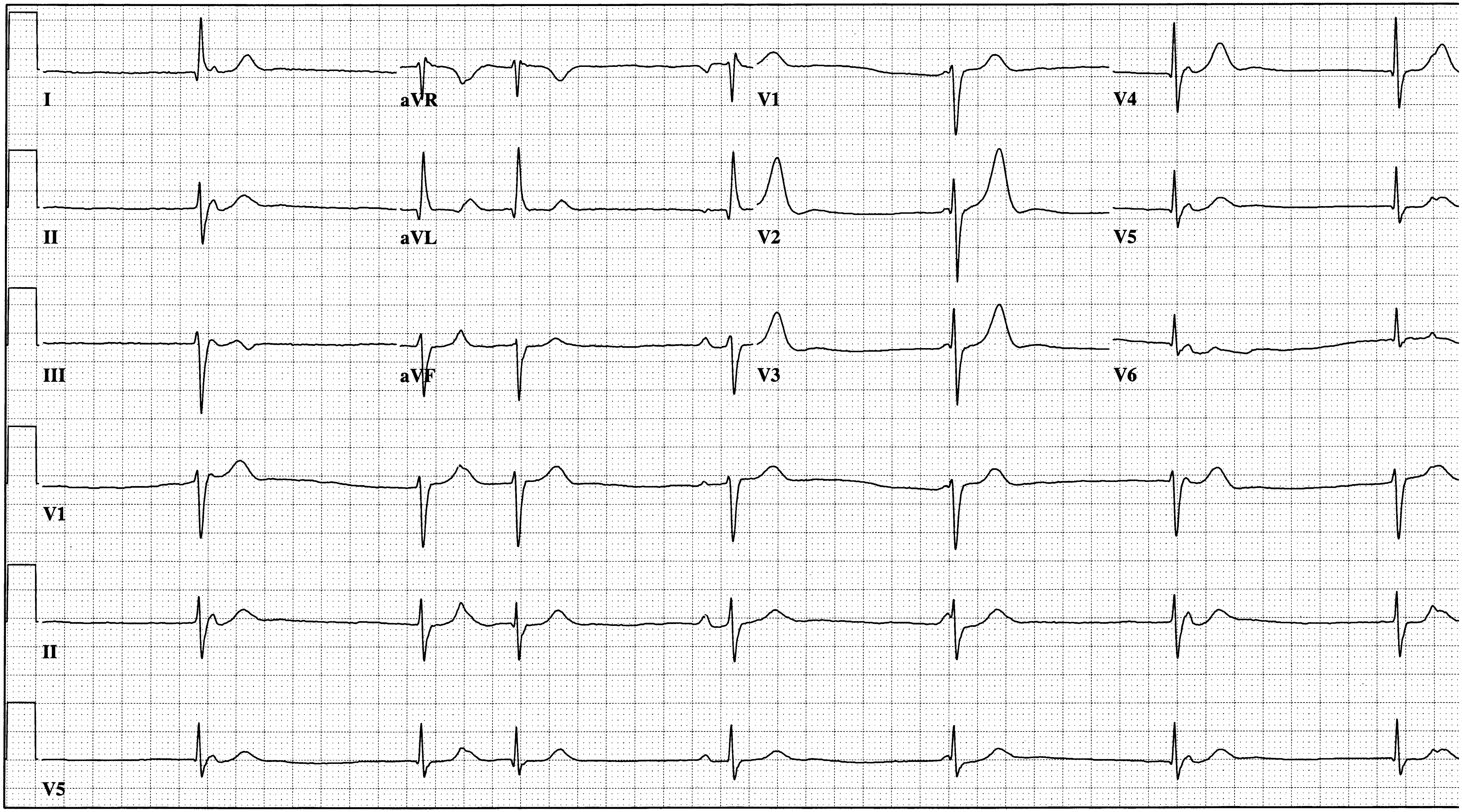
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 15

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

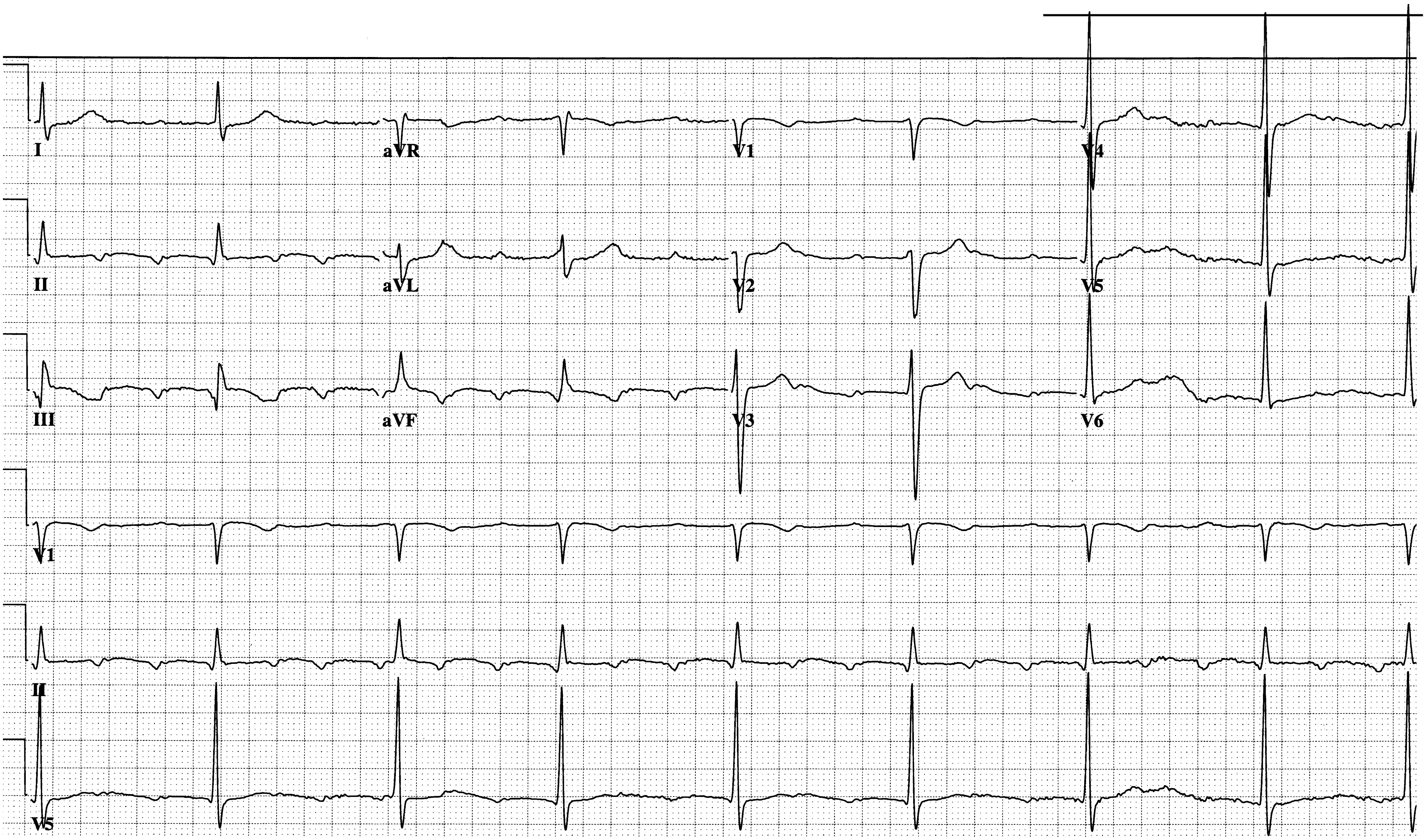
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 16

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

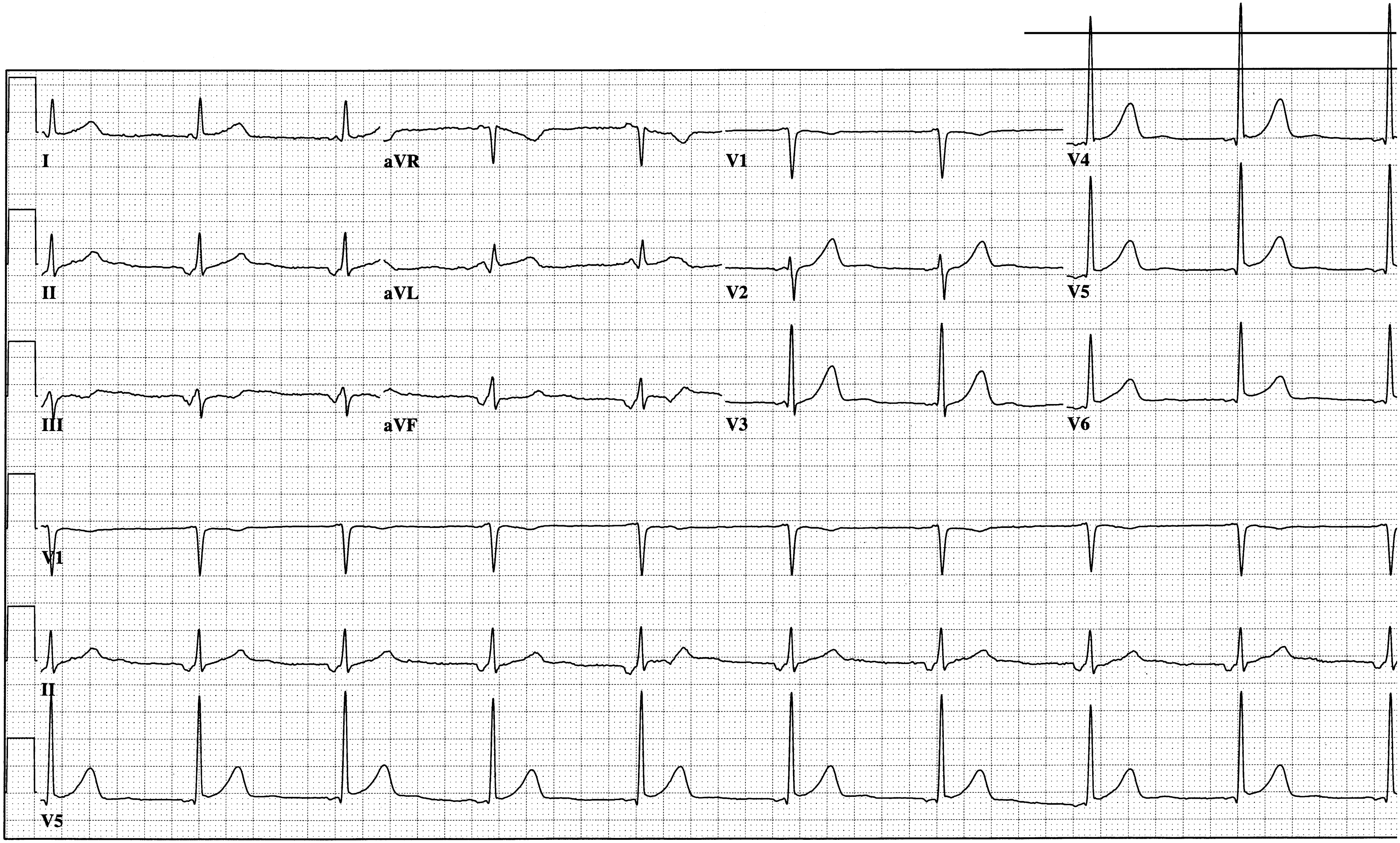
ST segment: ____________________

T wave: ____________________

QT interval: ____________________

U wave: ____________________

Diagnosis: ____________________



ECG 17

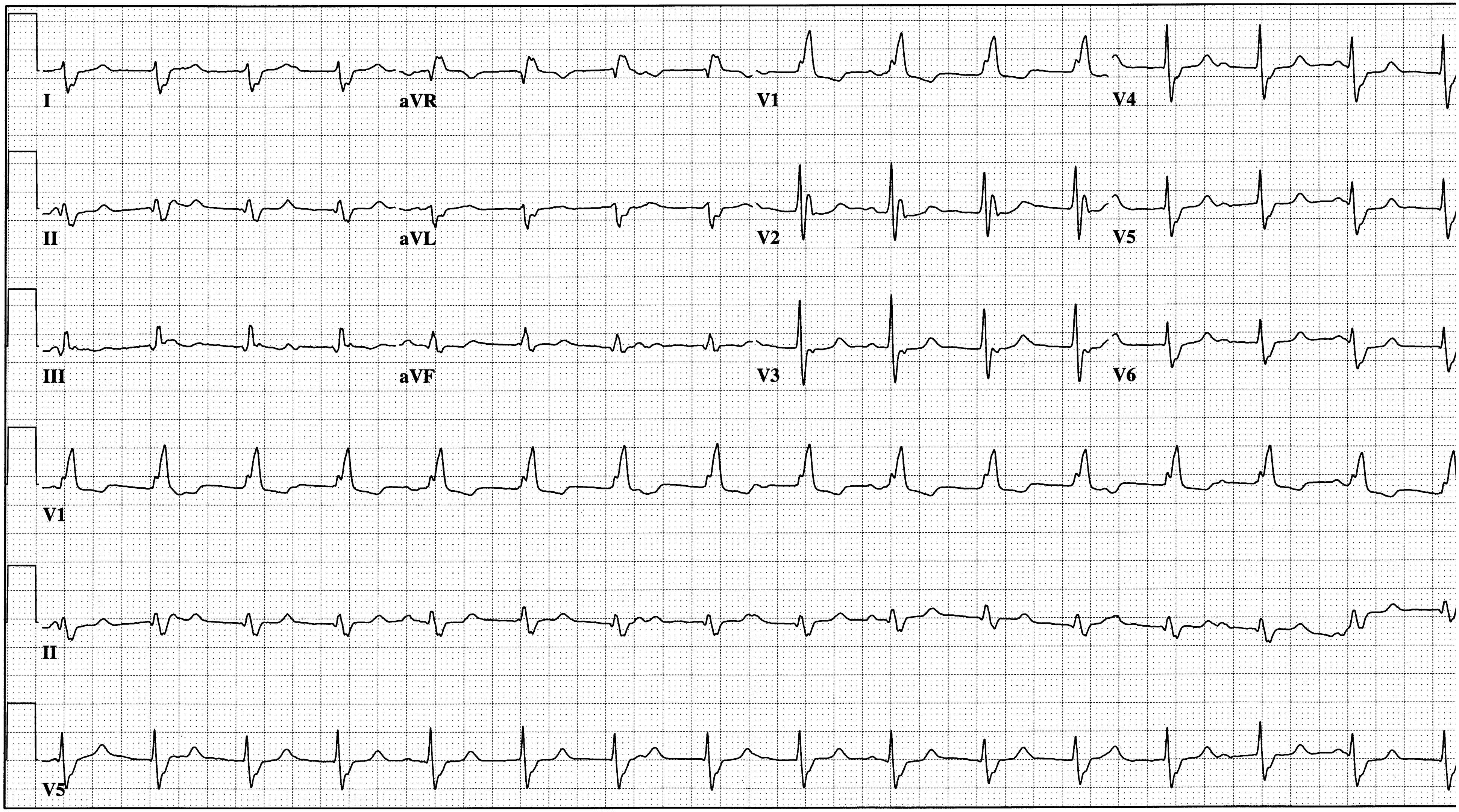
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

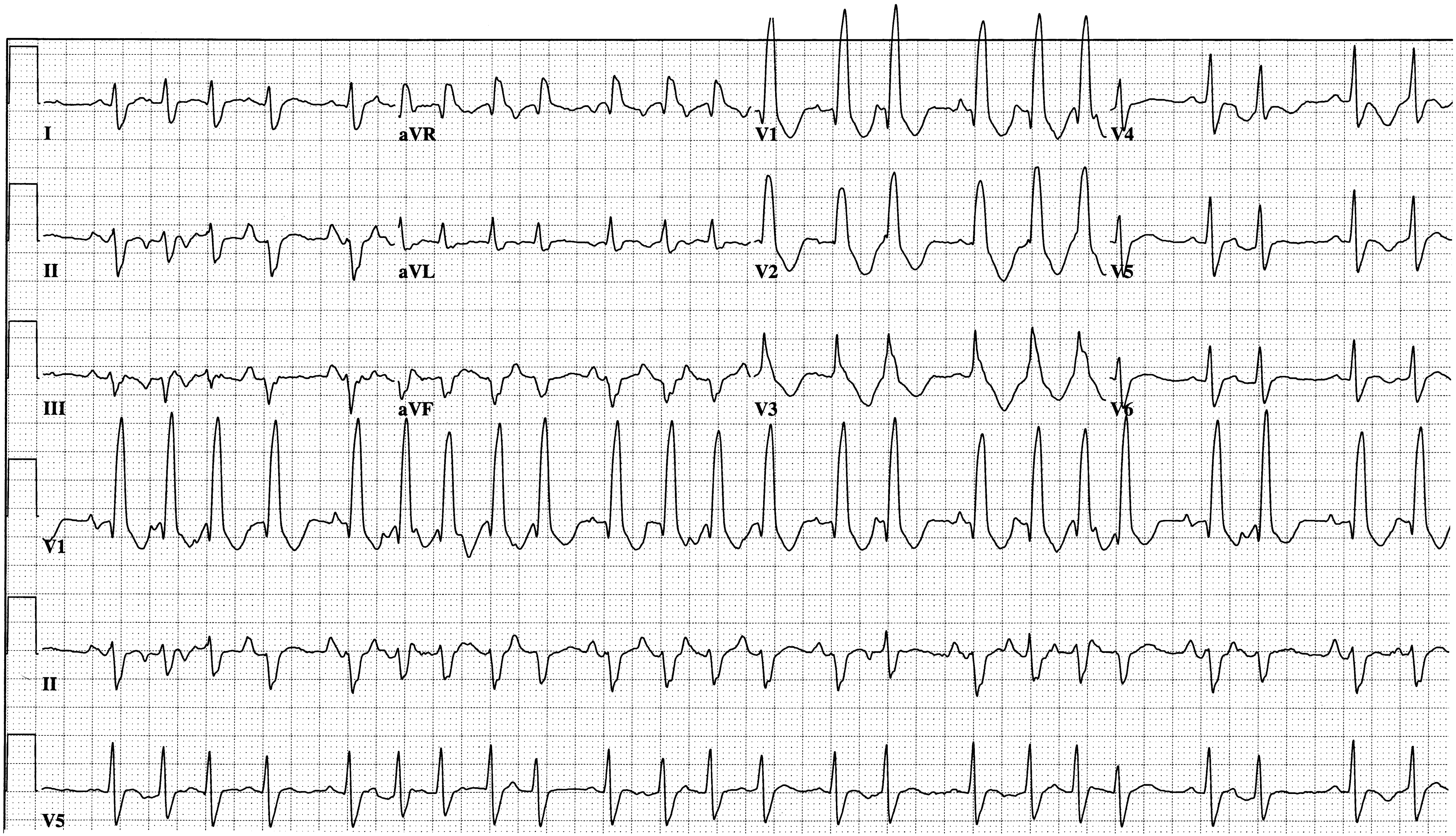
P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG 18

Atrial rate:	QRS complex:	ST segment:
Ventricular rate:	Axis:	T wave:
Rhythm:	Duration:	QT interval:
P wave:	Voltage:	U wave:
PR interval:	Morphology:	Diagnosis:



ECG 19

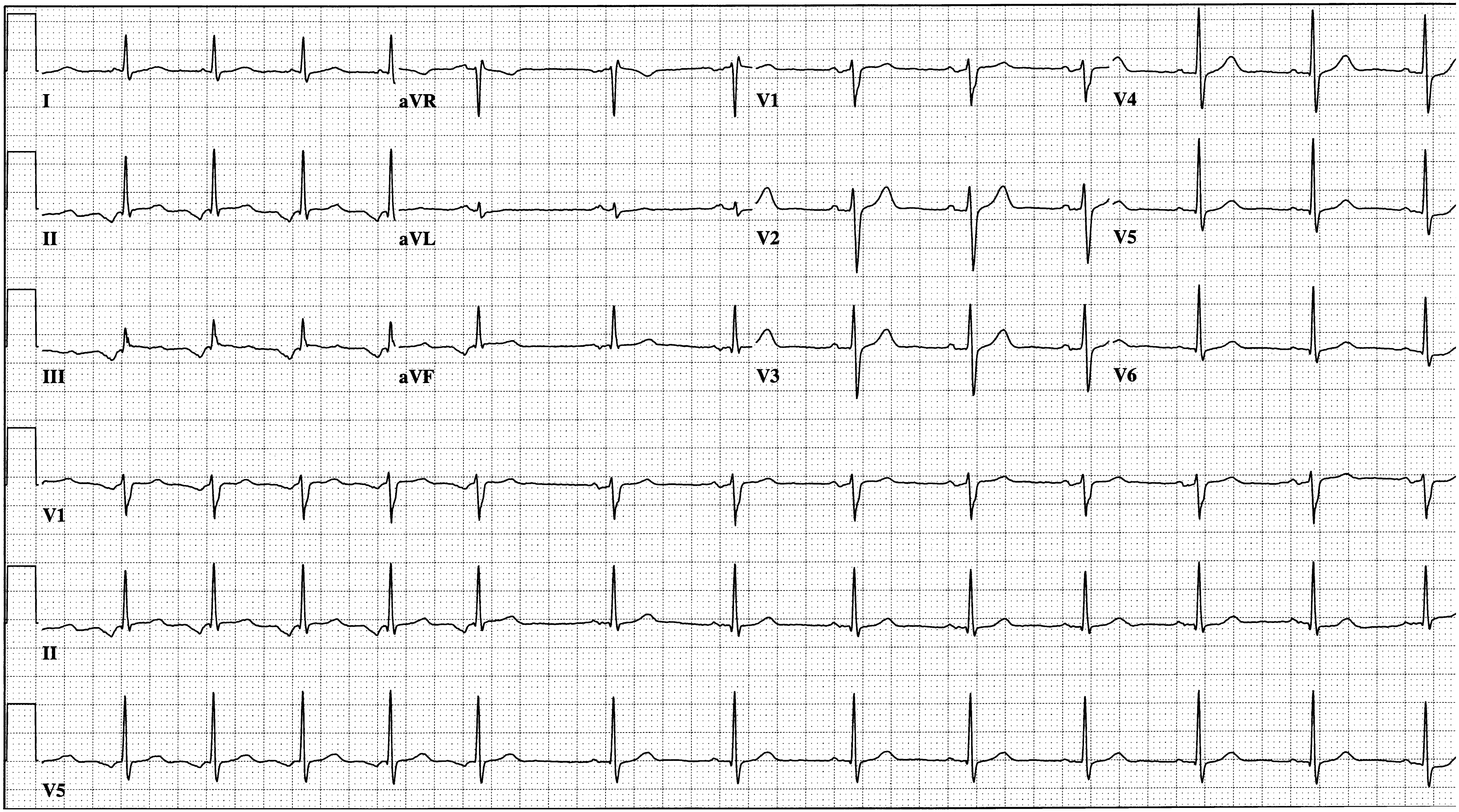
Atrial rate: __________ QRS complex: ST segment: __________

Ventricular rate: __________ Axis: __________ T wave: __________

Rhythm: __________ Duration: __________ QT interval: __________

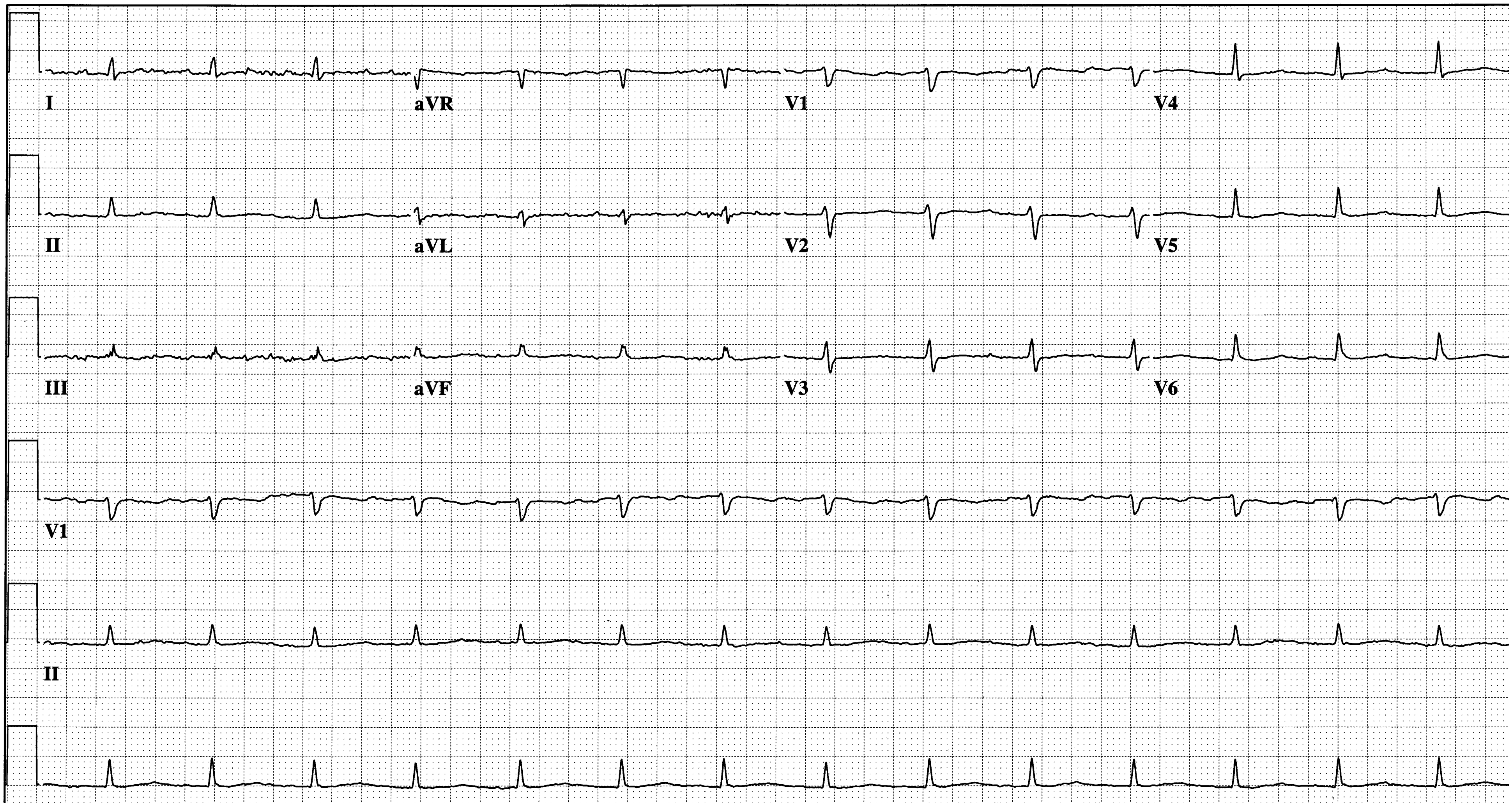
P wave: __________ Voltage: __________ U wave: __________

PR interval: __________ Morphology: __________ Diagnosis: __________



ECG 20

Atrial rate:	QRS complex:	ST segment:
Ventricular rate:	Axis:	T wave:
Rhythm:	Duration:	QT interval:
P wave:	Voltage:	U wave:
PR interval:	Morphology:	Diagnosis:



Ectopic Arrhythmias and Triggered Activity

Interpretations of Sample Tracings

ECG 1

Atrial rate: 135
Ventricular rate: 60
Rhythm: Sinus tachycardia with variable AV block
P wave: Normal
PR interval:
QRS complex:
  Axis: –60°
  Duration: 100 msec
  Voltage: Low voltage
  Morphology: Q waves in III, aVF, and V_1 to V_3
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 460 msec
U wave:
Diagnosis: Sinus tachycardia with variable AV block, left axis deviation, low voltage, old inferior MI, and probable old anteroseptal MI. It is possible that this rhythm represents ectopic atrial tachycardia.

ECG 2

Atrial rate: 200
Ventricular rate: 48
Rhythm: Atrial tachycardia with variable AV block
P wave:
PR interval:
QRS complex:
  Axis: 0°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Only very small R waves are present in the precordial leads
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 480 msec
U wave:
Diagnosis: Ectopic atrial tachycardia with variable AV block, and lack of R waves in the precordial leads suggesting an old anterior MI. This arrhythmia is suggestive of digoxin toxicity.

ECG 3

Atrial rate: 120
Ventricular rate: 120

Rhythm: Ectopic atrial tachycardia
P wave: Inverted in II, III, and aVF and upright in aVR
PR interval: 140 msec
QRS complex:
Axis: 45°
Duration: 80 msec
Voltage: Normal
Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 340 msec
U wave:
Diagnosis: Ectopic atrial tachycardia as evidenced by the abnormal P wave axis

ECG 4

Atrial rate: 160
Ventricular rate: 160
Rhythm: Ectopic atrial tachycardia
P wave: Inverted in II, III, and aVF and upright in aVR
PR interval: 130 msec
QRS complex:
Axis: 45°
Duration: 80 msec
Voltage: Normal
Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 320 msec
U wave:
Diagnosis: Ectopic atrial tachycardia as evidenced by the abnormal P wave axis

ECG 5

Atrial rate: Probably 80
Ventricular rate: 80
Rhythm: Accelerated junctional rhythm
P wave:
PR interval:
QRS complex:
Axis: −20°
Duration: 80 msec
Voltage: Normal
Morphology: Q waves in II, III, and aVF
ST segment: Normal
T wave: Inverted in I and aVL

QT interval: 390 msec
U wave: Normal
Diagnosis: Accelerated junctional rhythm with tiny P waves visible in front of the QRS complexes in II, III, and aVF, and Q waves in the same leads consistent with a previous inferior MI. This arrhythmia is suggestive of digoxin toxicity.

ECG 6

Atrial rate: 58
Ventricular rate: 58
Rhythm: Sinus bradycardia with a brief episode of what is probably ectopic atrial tachycardia with variable AV block
P wave: Normal in sinus rhythm
PR interval: 240 msec in sinus rhythm
QRS complex:
  Axis: 60°
  Duration: 90 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 430 msec
U wave:
Diagnosis: Sinus bradycardia with an episode of what appears to be ectopic atrial tachycardia.

ECG 7

Atrial rate:
Ventricular rate: 59
Rhythm: Atrial fibrillation, complete heart block, and a junctional escape rhythm
P wave:
P wave:
QRS complex:
  Axis: 40°
  Duration: 110 msec
  Voltage: Normal
  Morphology: Normal
ST segment: inferolateral ST segment depression
T wave: inverted in multiple leads
QT interval: 430 msec
U wave:
Diagnosis: Atrial fibrillation with complete heart block and a junctional escape rhythm, diffuse ST and T wave changes suggesting ischemia. The presence of complete heart block in atrial fibrillation suggests significant AV nodal disease, or, more frequently, treatment with an AV nodal blocking medication.

ECG 8

Atrial rate: 44
Ventricular rate: 44
Rhythm: Ectopic atrial bradycardia
P wave:
PR interval: 160 msec
QRS complex:
  Axis: 0°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Essentially Q waves in V_1 to V_4
ST segment: Normal
T wave: Normal
QT interval: 450 msec
U wave:
Diagnosis: Ectopic atrial bradycardia with a possible old anteroseptal MI

ECG 9

Atrial rate:
Ventricular rate: 55
Rhythm: Junctional rhythm
P wave:
PR interval:
QRS complex:
  Axis: −45°
  Duration: 125 msec, RBBB
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Nonspecific changes
QT interval: 440 msec
U wave:
Diagnosis: Junctional rhythm with probable retrograde P waves, best seen in III, aVF and V_1 to V_6, left axis deviation, and RBBB

ECG 10

Atrial rate: 80
Ventricular rate: 80
Rhythm: Wandering atrial pacemaker
P wave:
PR interval:

QRS complex:
Axis: –20°
Duration: 90 msec
Voltage: Normal
Morphology: Normal
ST segment: Nonspecific changes
T wave: Normal
QT interval: 390 msec
U wave: Prominent U waves in V_2 and V_3
Diagnosis: Wandering atrial pacemaker with several P wave morphologies, varying PR intervals and a rate less than 100

ECG 11

Atrial rate: 90
Ventricular rate: 90
Rhythm: Wandering atrial pacemaker with occasional nonconducted P waves
P wave:
PR interval:
QRS complex:
Axis: –60°
Duration: 100 msec
Voltage: Normal
Morphology: Normal
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 350 msec
U wave:
Diagnosis: Wandering atrial pacemaker with occasional nonconducted P waves and left axis deviation

ECG 12

Atrial rate: 110
Ventricular rate: 110
Rhythm: Ectopic atrial tachycardia with frequent premature beats
P wave:
PR interval: Variable
QRS complex:
Axis: –10°
Duration: 80 msec
Voltage: Normal
Morphology: Normal

ST segment: Normal
T wave: Nonspecific changes
QT interval: 320 msec
U wave:
Diagnosis: Ectopic atrial tachycardia with frequent premature beats and variable but prolonged PR intervals

ECG 13

Atrial rate: 55
Ventricular rate: 55
Rhythm: Junctional rhythm with retrograde atrial activation
P wave:
PR interval:
QRS complex:
  Axis: 75°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Delayed precordial transition
ST segment: Nonspecific changes
T wave: Normal
QT interval: 430 msec
U wave:
Diagnosis: Junctional rhythm with retrograde P waves, best seen in V_1. There is also delayed precordial transition suggesting an old anteroseptal MI.

ECG 14

Atrial rate: 40
Ventricular rate: 40
Rhythm: Sinus bradycardia with a competing junctional rhythm
P wave: Normal
PR interval:
QRS complex:
  Axis: −40°
  Duration: 105 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 550 msec
U wave:
Diagnosis: Sinus bradycardia with a competing junctional pacemaker. In this tracing the junctional rhythm is slightly faster than the sinus rhythm, and therefore usurps control of the ventricular rhythm.

ECG 15

Atrial rate: 150
Ventricular rate: 50
Rhythm: Ectopic atrial tachycardia with high grade AV block
P wave:
PR interval:
QRS complex:
  Axis: 70°
  Duration: 105 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Nonspecific changes
QT interval: 480 msec
U wave:
Diagnosis: Ectopic atrial tachycardia with high grade AV block. There are slight variations in some of the R-R intervals suggesting that there is some communication between the atria and ventricles. This rhythm is suggestive of digoxin toxicity.

ECG 16

Atrial rate: 55
Ventricular rate: 55
Rhythm: Junctional rhythm
P wave:
PR interval: 120 msec
QRS complex:
  Axis: 0°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 430 msec
U wave:
Diagnosis: Junctional rhythm

ECG 17

Atrial rate: 75
Ventricular rate: 90
Rhythm: Sinus rhythm with complete heart block with an accelerated junctional rhythm
P wave:
PR interval:

QRS complex:
Axis: 150°
Duration: 140 msec, RBBB, left posterior fascicular block (LPFB)
Voltage: Normal
Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 390 msec
U wave:
Diagnosis: Sinus rhythm with complete heart block with an accelerated junctional rhythm, right axis deviation, RBBB, Left posterior fascicular block (right axis deviation >100°, deep S wave in I and small Q wave in III, and an IVCD)

ECG 18

Atrial rate: 145
Ventricular rate: 145
Rhythm: Multifocal atrial tachycardia
P wave:
PR interval:
QRS complex:
Axis: (90°
Duration: 130 msec, RBBB
Voltage: Normal
Morphology: Q waves in III and aVF
ST segment: Normal
T wave: Normal
QT interval: 340 msec
U wave:
Diagnosis: Multifocal atrial tachycardia with left axis deviation and RBBB, and probable old inferior MI

ECG 19

Atrial rate: 90 in ectopic atrial rhythm and 75 in sinus rhythm
Ventricular rate: 90 in ectopic atrial rhythm and 75 in sinus rhythm
Rhythm: Ectopic atrial rhythm converting to sinus rhythm
P wave: Normal in sinus rhythm
PR interval: 160 msec
QRS complex:
Axis: 60°
Duration: 80 msec
Voltage: Normal
Morphology: Normal
ST segment: Nonspecific changes
T wave: Normal

QT interval: 360 msec
U wave:
Diagnosis: Ectopic atrial rhythm converting to sinus rhythm. The paroxysmal nature of this rhythm is not typical of ectopic arrhythmias.

ECG 20

Atrial rate:
Ventricular rate: 86
Rhythm: Accelerated junctional rhythm
P wave:
PR interval:
QRS complex:
  Axis: 60°
  Duration: 80 msec
  Voltage: Low voltage
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 480 msec
U wave:
Diagnosis: Accelerated junctional rhythm with a prolonged QT interval

Day 7

Extrasystoles and Preexcitation Syndromes

I. Extrasystoles

A. Mechanisms of extrasystoles

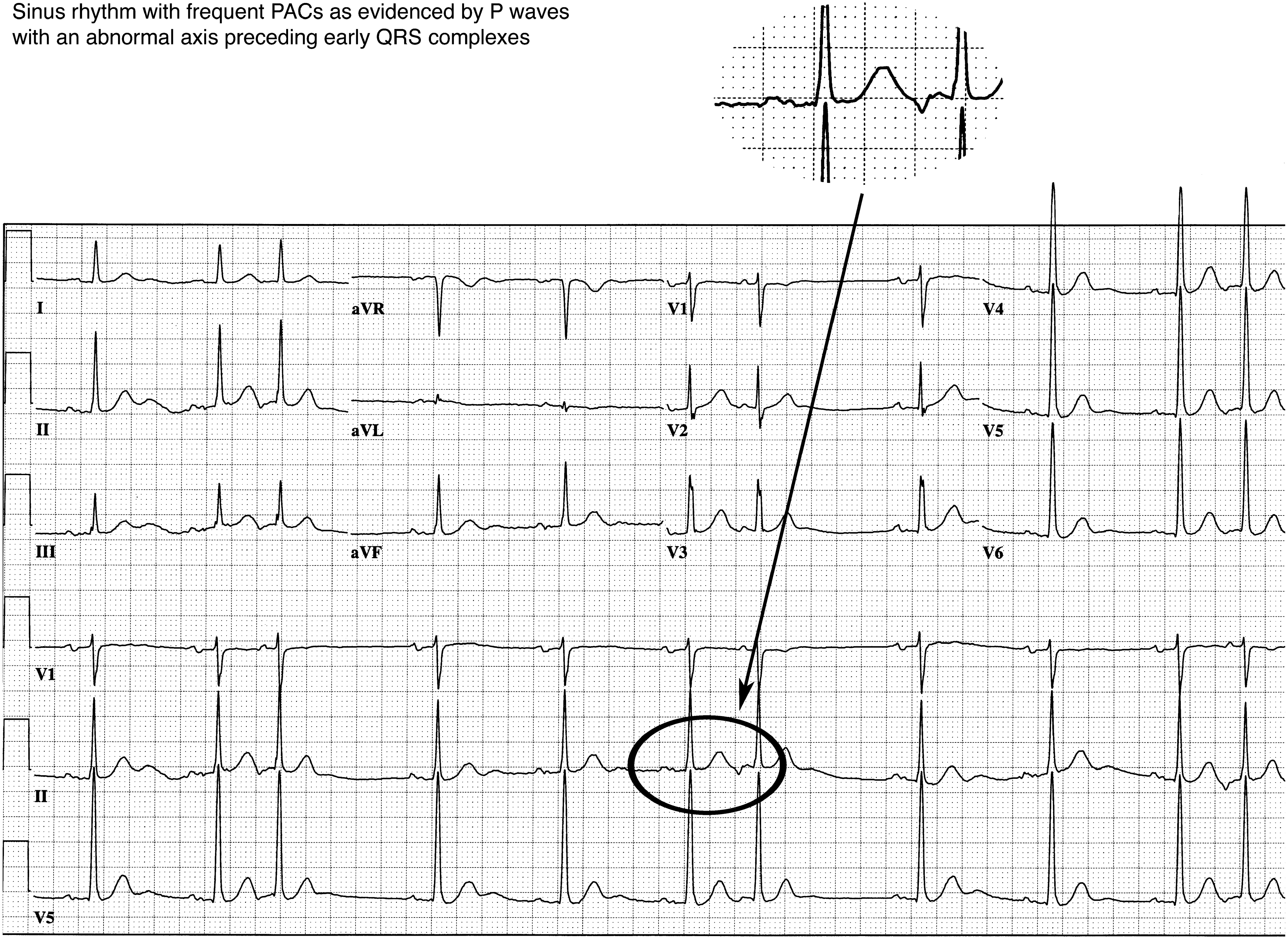
1. Reentry
    a. Most extrasystoles, particularly if they are monomorphic, bear a constant relationship to the preceding QRS complex (a *fixed coupling interval*).
    b. The vast majority of these complexes probably represent a reentrant mechanism (each beat represents one trip around a reentrant pathway).
2. Parasystole
    a. Parasystole occurs when an *ectopic focus* fires independently of the basic rhythm.
    b. If the parasystolic focus is not reset by the basic rhythm, the focus is said to be *protected*
    c. There is a constant interval between ectopic depolarizations, but the ectopic focus will manifest itself only whenever it finds the atrium or ventricle not refractory.
    d. Parasystole is very uncommon.
3. Escape
    a. Escape is a normal phenomenon that occurs when there is a sufficient pause to allow a lower pacemaker to depolarize.
    b. Common examples are junctional or ventricular escape mechanisms.
4. Unclassified—some extrasystoles do not fall easily into any of these categories and may remain undiagnosed.

B. Atrial extrasystoles (Day 7-01) (Day 7-02) (Day 7-03)

1. Most atrial extrasystoles, or premature atrial complexes (PACs), are reentrant.
2. Atrial extrasystoles are preceded by a P wave that usually has abnormal morphology, indicative of the abnormal direction of atrial depolarization.
3. The QRS complex is narrow unless there is a preexisting intraventricular conduction defect.

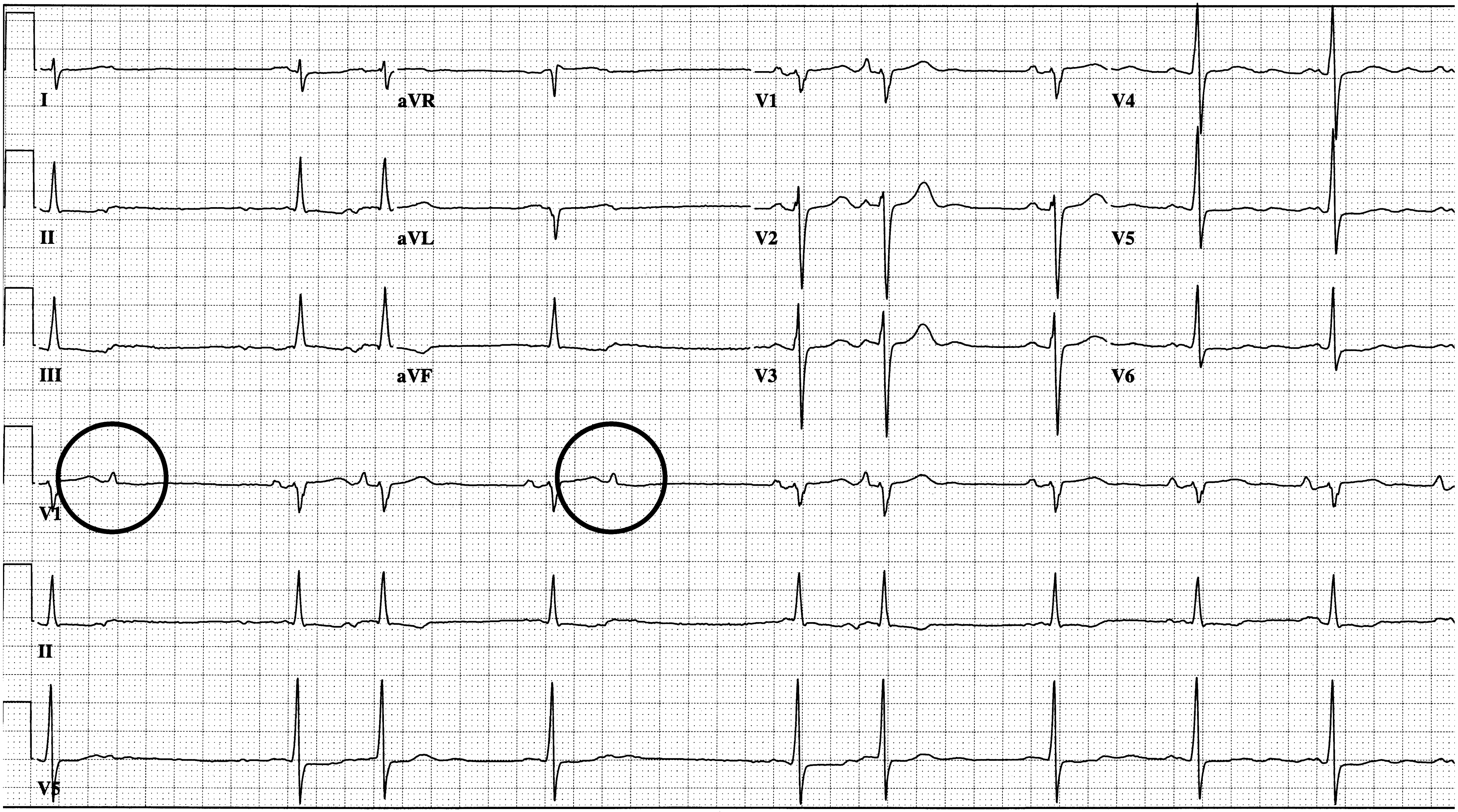
DAY 7-01

Sinus rhythm with frequent PACs as evidenced by P waves with an abnormal axis preceding early QRS complexes



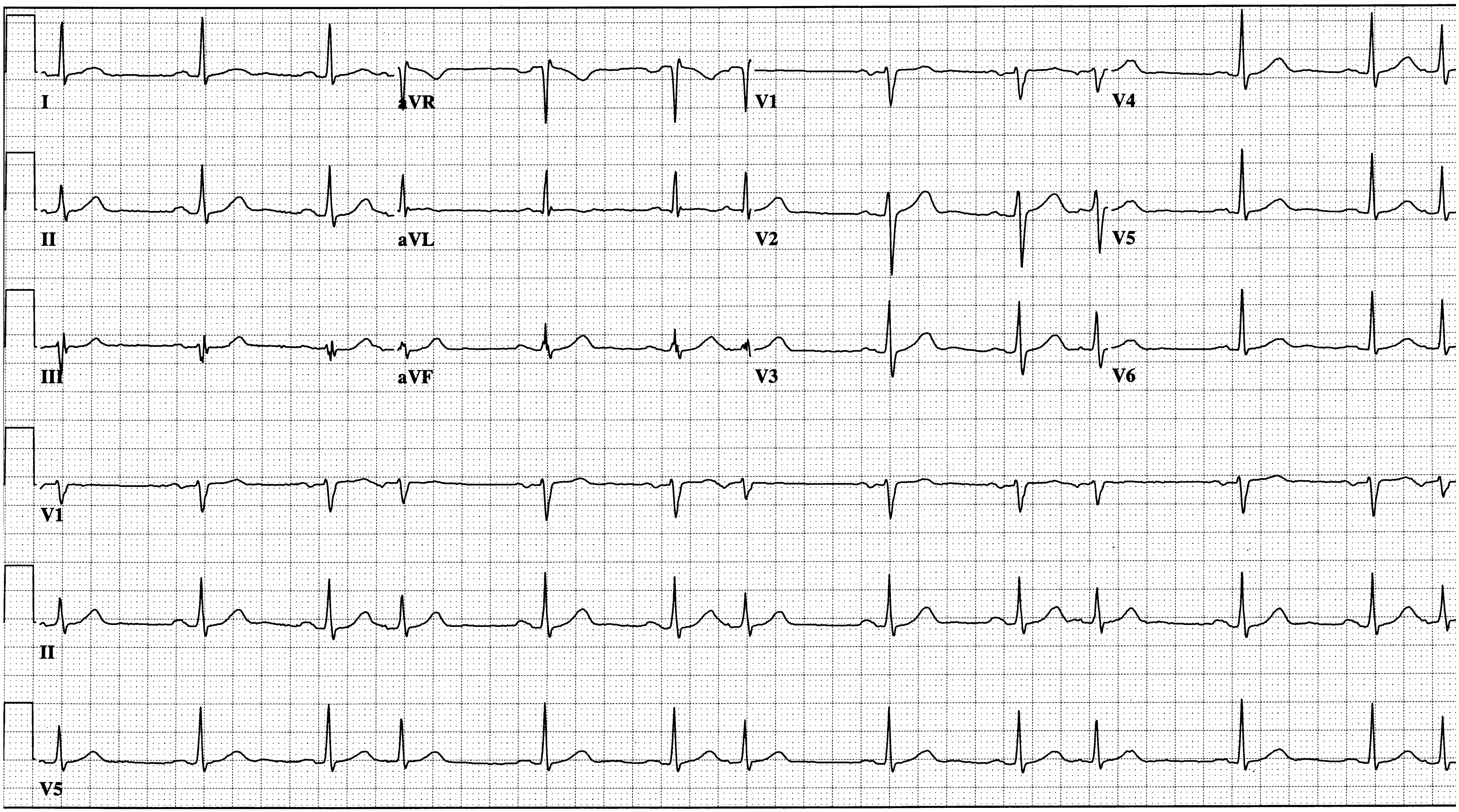
DAY 7-02

Sinus rhythm with frequent PACs, some nonconducted



DAY 7-03

PACs occurring every third beat in a pattern of atrial trigeminy

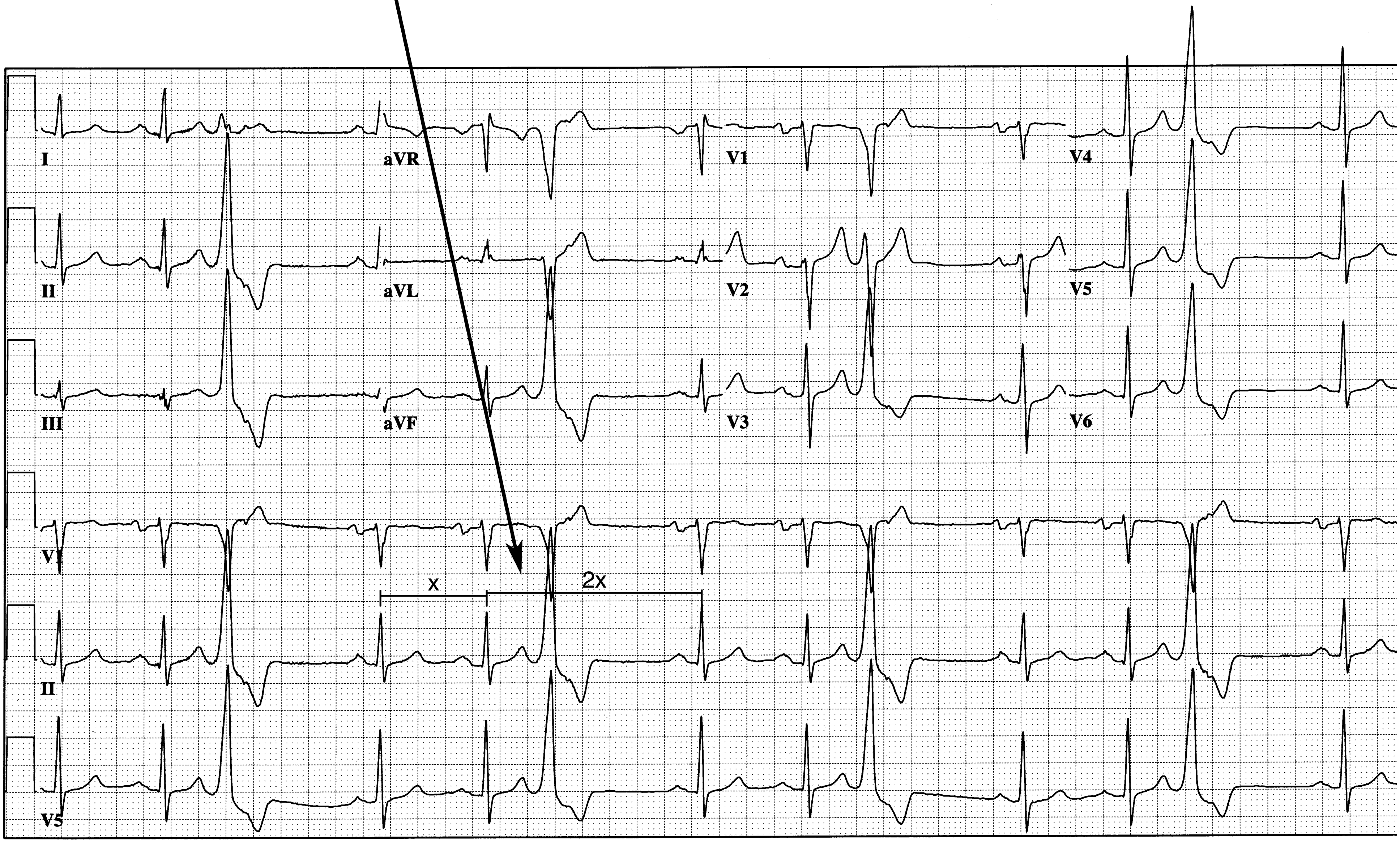


4. Occasionally, the QRS complex may be wide (*aberrant*) when one of the bundle branches is not fully repolarized.
5. An atrial extrasystole usually resets the sinus mechanism and, therefore, is not followed by a compensatory pause (see below).
6. If an atrial extrasystole is very early, the ventricle may be refractory and not depolarize ("the commonest cause of a pause is a nonconducted atrial extrasystole"—Marriott).

C. Ventricular extrasystoles (Day 7-04) (Day 7-05) (Day 7-06)
   1. Most ventricular extrasystoles are also reentrant
   2. Ventricular extrasystoles are not preceded by a P wave
   3. The QRS complex is obviously wide
   4. Ventricular extrasystoles usually do not reset the atrial rate and are frequently followed by a *compensatory pause.*
   5. A ventricular extrasystole may cause retrograde depolarization of the AV node, which results in a lengthening of the subsequent PR interval—a phenomenon known as concealed retrograde conduction.

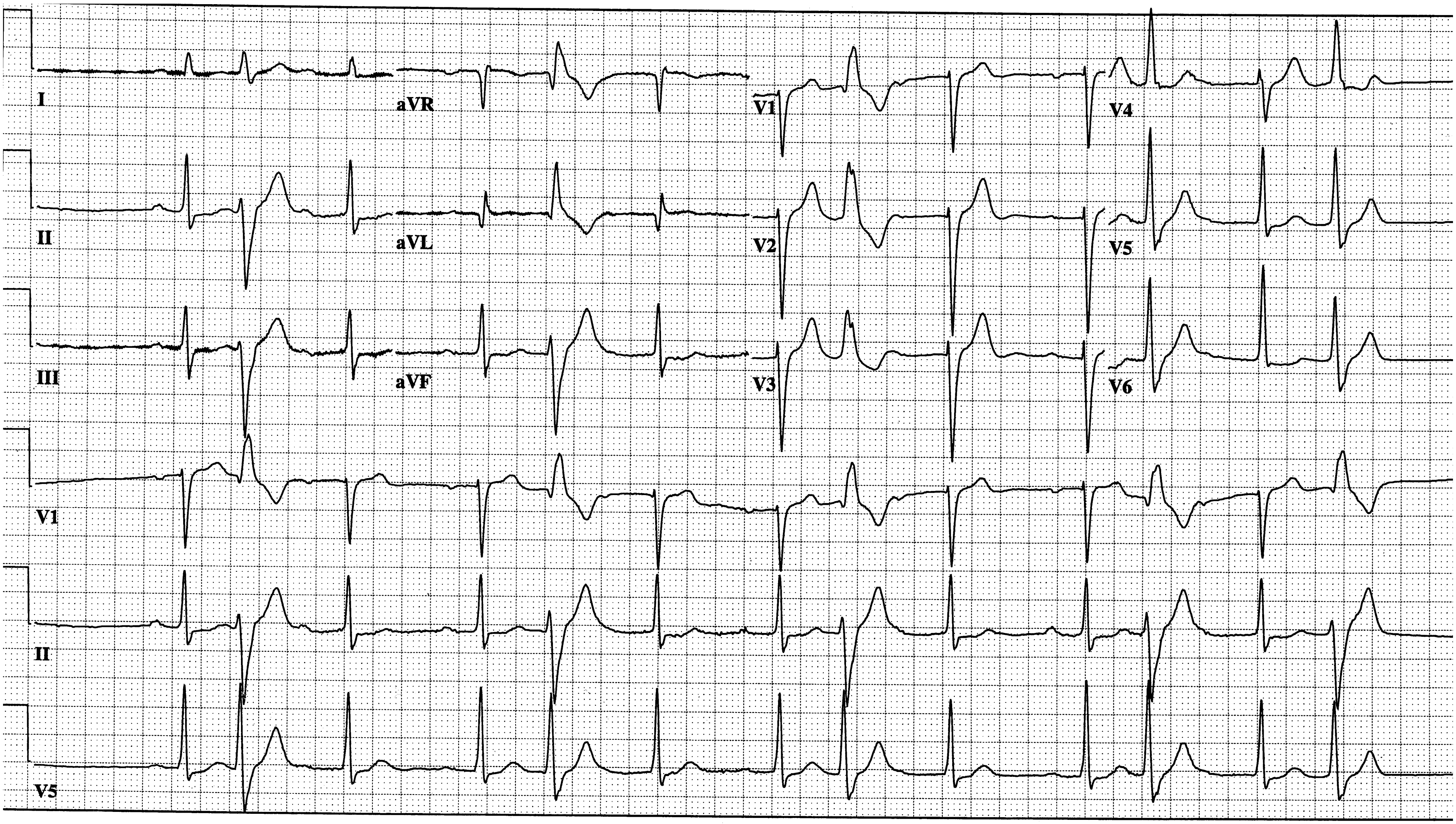
DAY 7-04

Sinus rhythm with frequent PVCs in a pattern trigeminy. Note that the interval surrounding the PVCs is twice the interval of the sinus beats; this is called a compensatory pause.



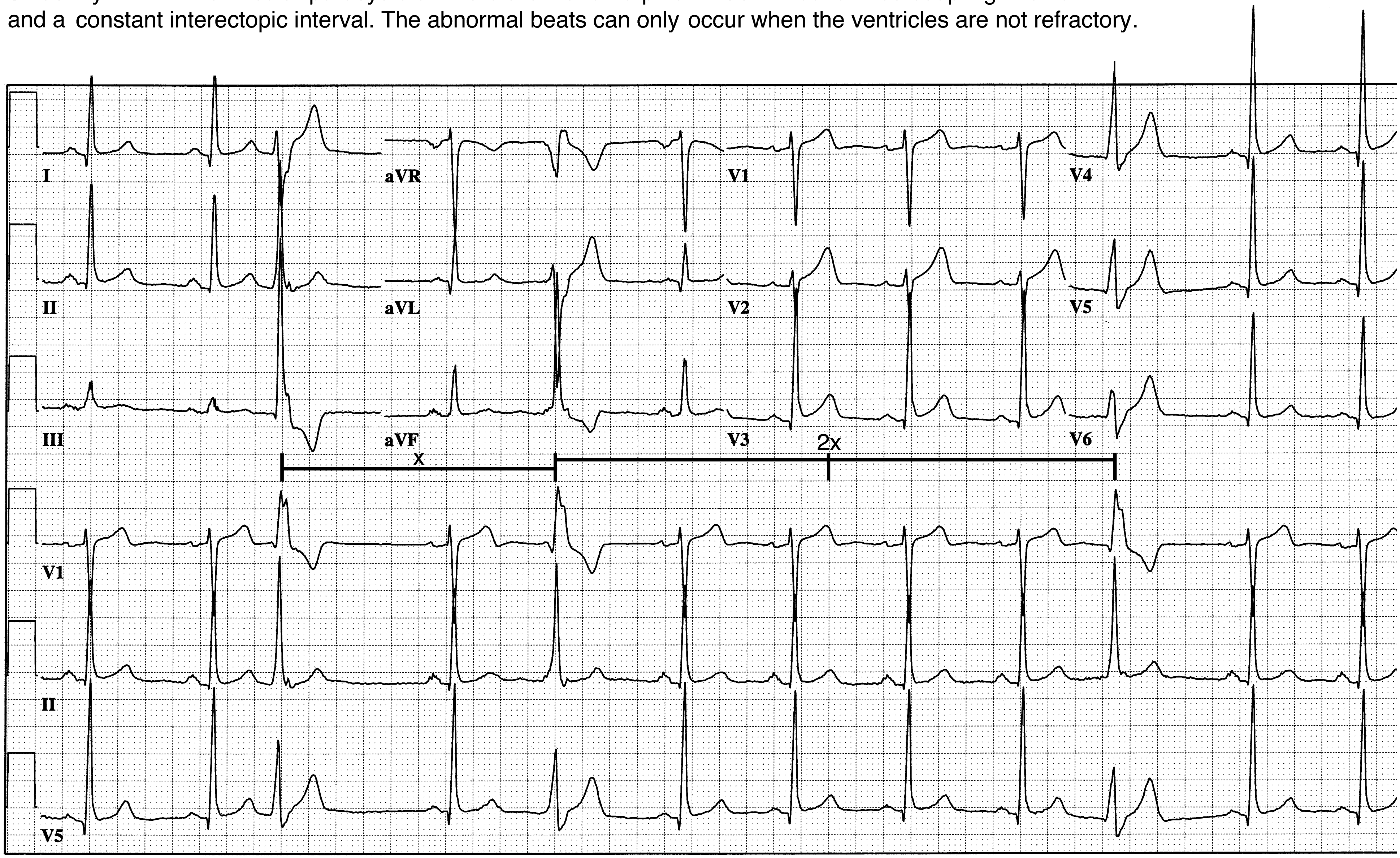
DAY 7-05

Sinus rhythm with PVCs which are said to be interpolated as they are not associated with a compensatory pause



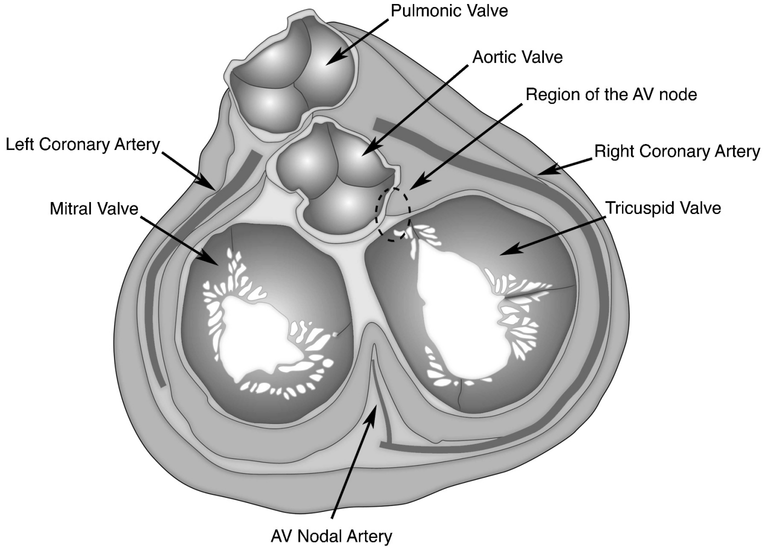
DAY 7-06

Sinus rhythm with ventricular parasystole. There are monomorphic PVCs without a fixed coupling interval and a constant interectopic interval. The abnormal beats can only occur when the ventricles are not refractory.



II. Preexcitation

A. The origin of accessory pathways

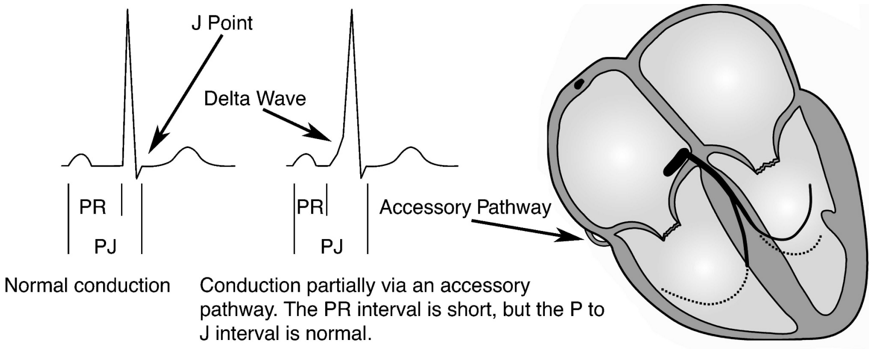


The heart in diastole as viewed from above with the atria removed. The AV ring is a fibrous structure that supports the mitral and tricuspid valves. It also serves as an insulating plate between the atria and ventricles. The AV node is normally the only electrical connection between the upper and lower chambers. Accessory pathways are residual muscle fibers that may occur anywhere around the periphery of the AV ring, and these fibers form the electrical pathways involved in the Wolff-Parkinson-White syndrome.

1. *In utero*, the atria and ventricles are eventually separated by a fibrous plate called the AV ring.
2. The function of the AV ring is to provide support for the mitral and tricuspid valves and to electrically insulate the atria and ventricles.
3. The AV node is the only structure that should allow conduction through the AV ring.
4. Overexuberant separation of the atria and ventricles produces congenital 3° AV block (see Day 4).
5. If there is incomplete separation, residual muscle fibers may bridge the AV ring and form accessory electrical pathways.

B. Characteristics of accessory pathways
1. Accessory pathways usually do not have the conduction delay properties of the AV node.
2. Another way of saying this is that the refractory period of the accessory pathway is typically shorter than the AV node.
3. Accessory pathways can be located anywhere around the AV ring, and may be multiple.

C. ECG manifestations of accessory pathways

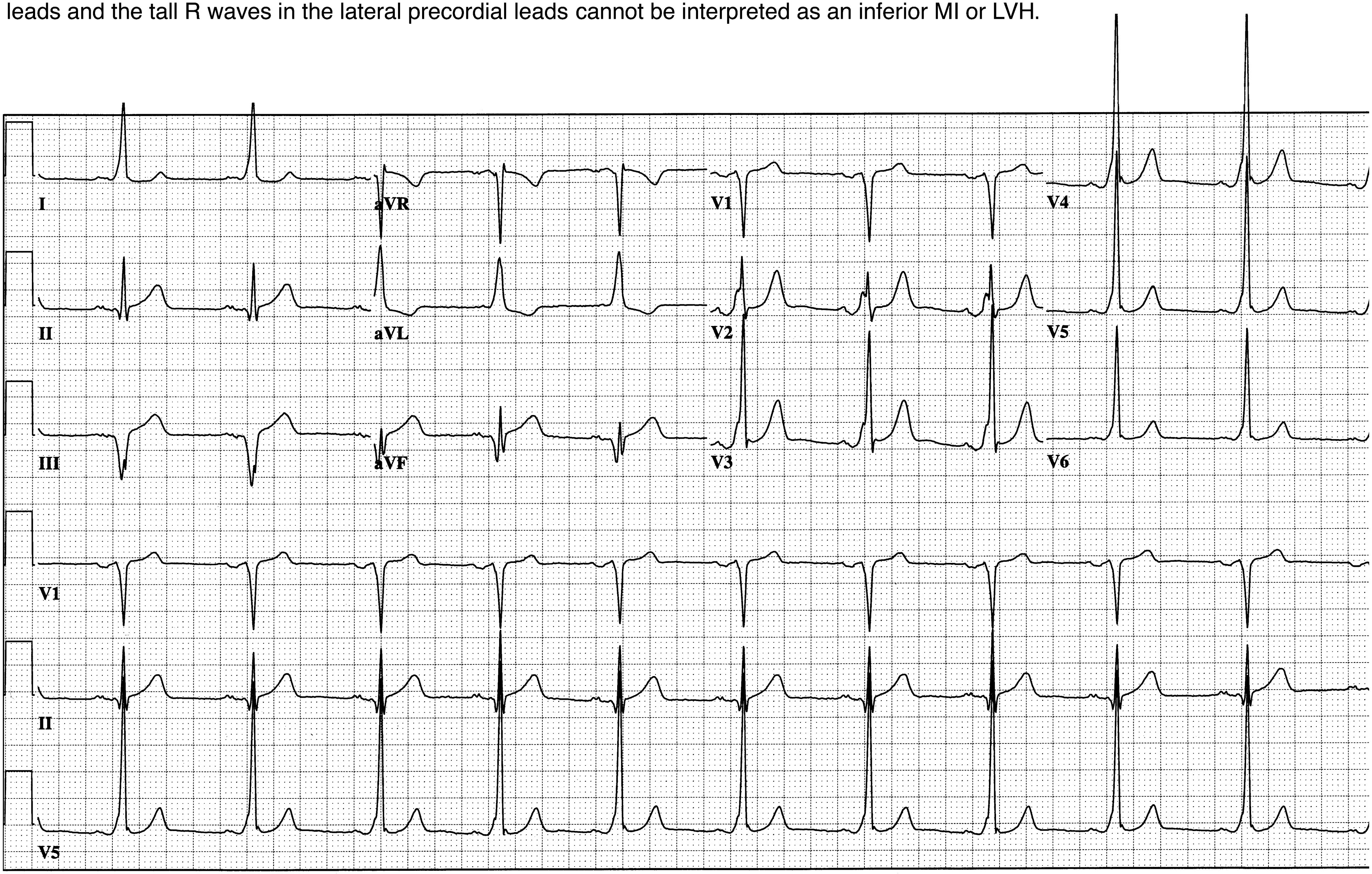


The ECG complex in WPW with partial conduction down an accessory pathway. The portion of the ventricle which is depolarized early produces the characteristic delta wave and shortens the PR interval.

1. The delta wave
   a. After atrial systole, the shorter refractory period of the accessory pathway may produce an early depolarization of part of the right or left ventricle.
   b. The early depolarization of part of the ventricle causes the QRS complex to intrude into the PR interval producing the characteristic delta wave.
   c. The location of the delta wave helps localize the site of the accessory pathway.
   d. The presence of the delta wave and its attendant arrhythmias is known as the Wolff-Parkinson-White (WPW) syndrome.
2. Limitations to ECG interpretation (Day 7-07) (Day 7-08)
   a. The delta wave may be inverted in various leads and may appear as a Q wave, producing a *pseudoinfarct* pattern.
   b. QRS voltage is an unreliable indicator of LVH
   c. ST and T wave changes are unreliable indicators of ischemia unless serial ECGs are available.

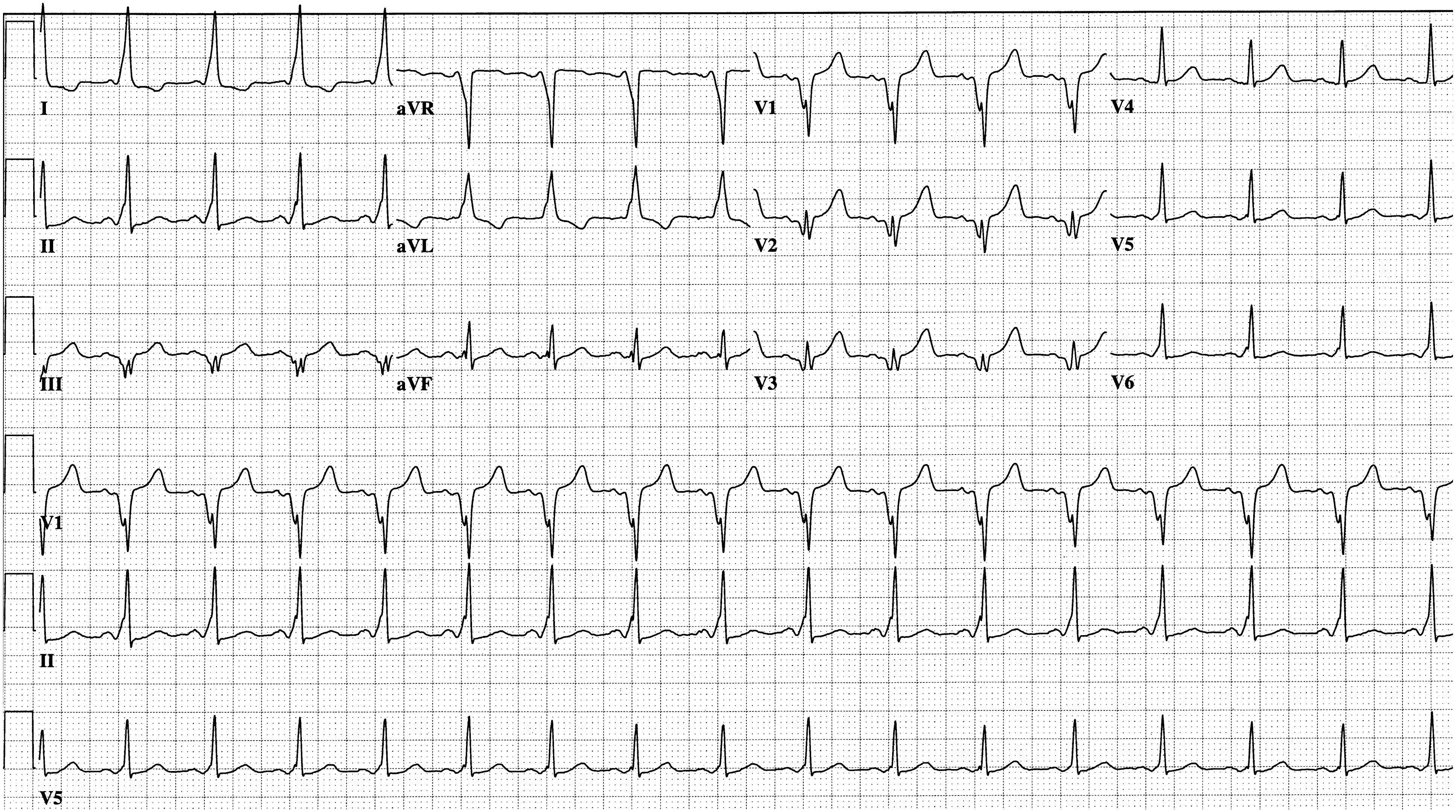
DAY 7-07

WPW as evidenced by prominent delta waves and a short PR interval in multiple leads. The Q waves in the inferior leads and the tall R waves in the lateral precordial leads cannot be interpreted as an inferior MI or LVH.

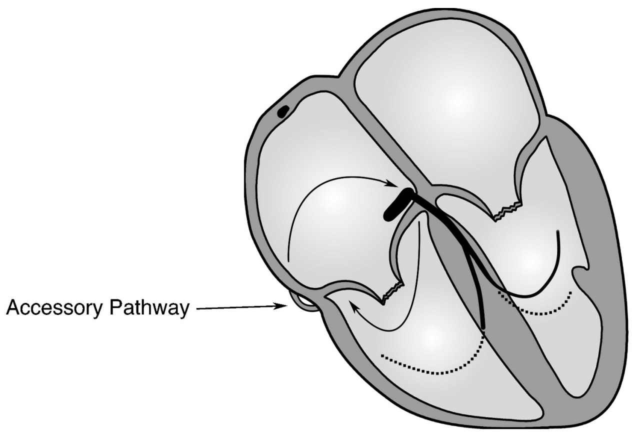


DAY 7-08

WPW as evidenced by prominent delta waves and a short PR interval in multiple leads. The Q waves in V_1-V_3 cannot be interpreted as an anterior MI.



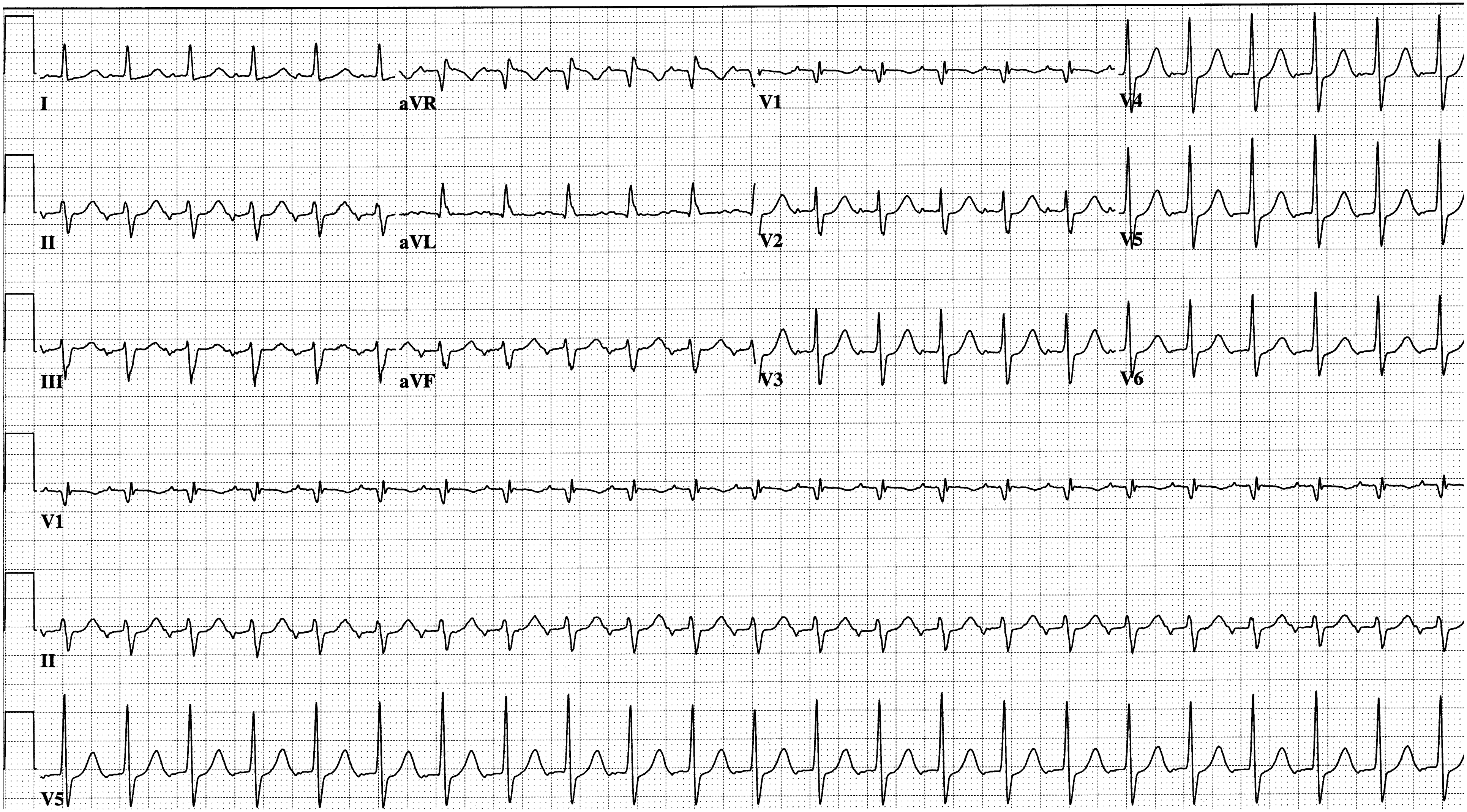
D. Accessory pathways and arrhythmias
   1. Reentrant arrhythmias involving an accessory pathway
      a. The accessory pathway may form one limb of a reentrant loop, with the AV node as the other limb.
      b. A reentrant arrhythmia can occur with the wave of depolarization going down the AV node and retrograde up the accessory pathway (antegrade conduction).
      c. As long as there is no concomitant intraventricular conduction defect (IVCD), the QRS complex with antegrade conduction down the AV node will be narrow (no delta wave). (Day 7-09)



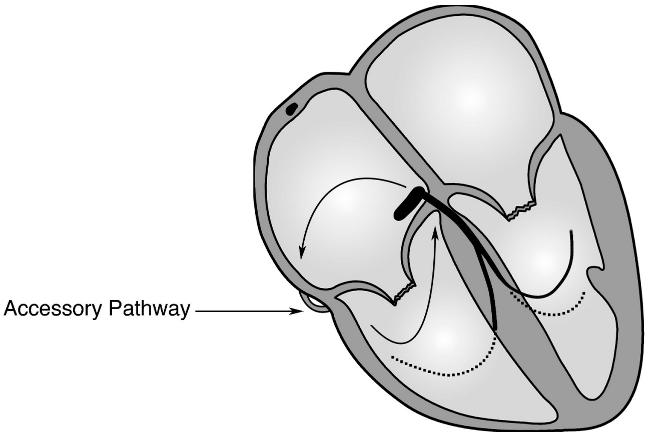
Antedromic reciprocating tachycardia in which an impulse travels antegrade down the AV node and retrograde up the accessory pathway. Since the ventricles are being activated normally, this will produce a narrow complex tachycardia.

DAY 7-09

A narrow complex tachycardia in a patient with known WPW. In this case, electrophysiology studies verified that this is an antedromic reciprocating tachycardia.



   d. If the depolarization proceeds down the accessory pathway and back up through the AV node (retrograde conduction), the QRS complex will be wide (and resemble VT). (Day 7-10)
   e. Maneuvers or medications, which block the AV node, may terminate these arrhythmias (but see below).
2. Atrial fibrillation and atrial flutter with an accessory pathway (Day 7-11)
   a. If atrial fibrillation or flutter occurs in the presence of an accessory pathway, many impulses may be conducted through the pathway so that the ventricular response is very rapid.
   b. The QRS complex is usually wide and bizarre, and may be irregular if atrial fibrillation is present.
   c. Interventions, which increase AV nodal block may speed conduction through the accessory pathway and are *contraindicated.*
   d. These arrhythmias should be treated with urgent electrical cardioversion and subsequent ablation of the accessory pathway.



Orthodromic reciprocating tachycardia in which an impulse travels antegrade down an accessory pathway and retrograde up the AV node. Since the ventricles are being activated from an abnormal location, this will produce a wide complex tachycardia.

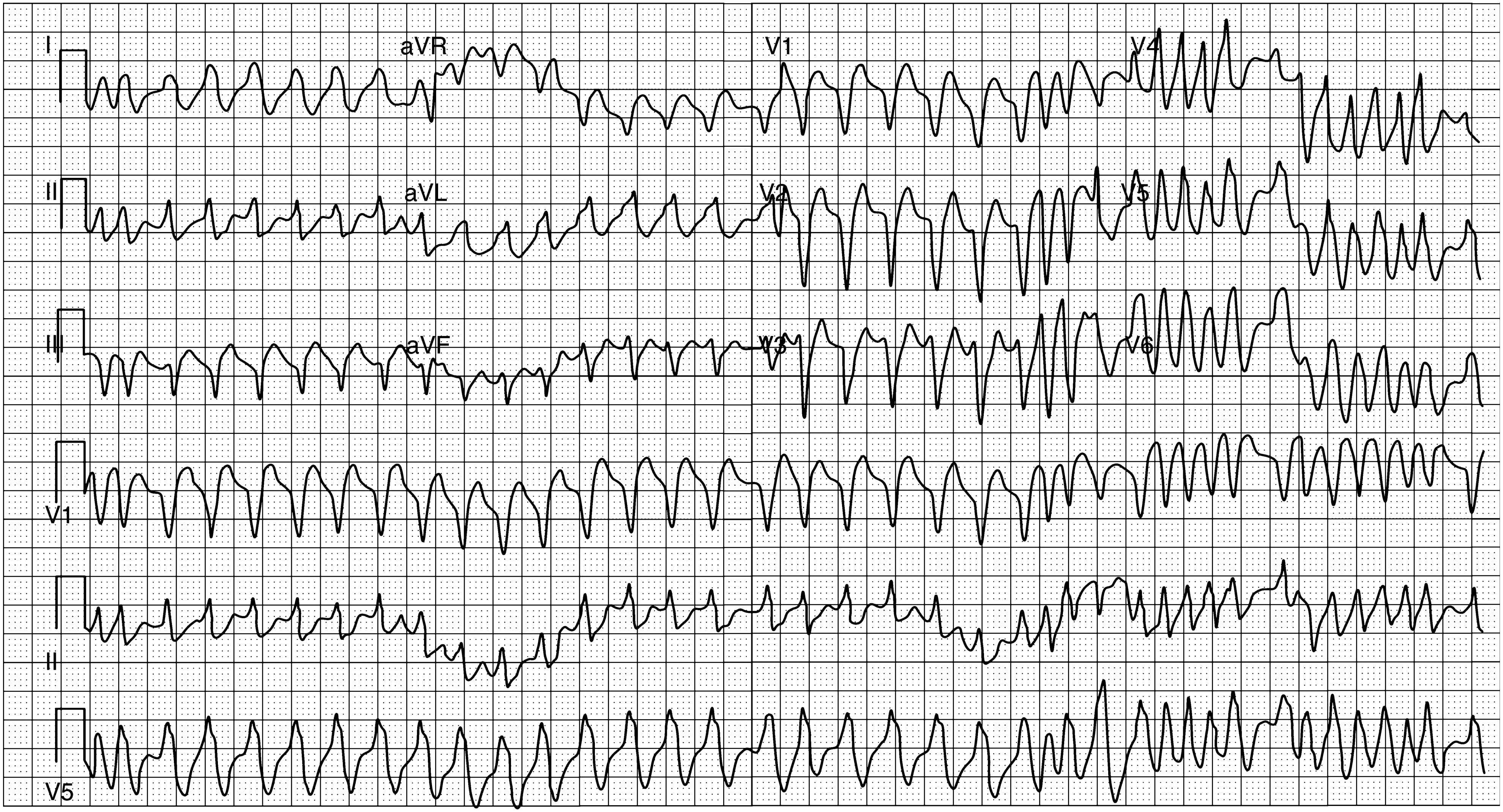
DAY 7-10

A wide complex tachycardia in a patient with known WPW. In this case, electrophysiology studies verified that this is an orthodromic reciprocating tachycardia.

DAY 7-11

Atrial fibrillation in a patient with WPW. Note the extremely rapid rate, the wide, variable QRS complexes, and the variable rate.

(adapted from the American College of Cardiology's *Cardiosource* files)



Sample Tracings
ECG 1

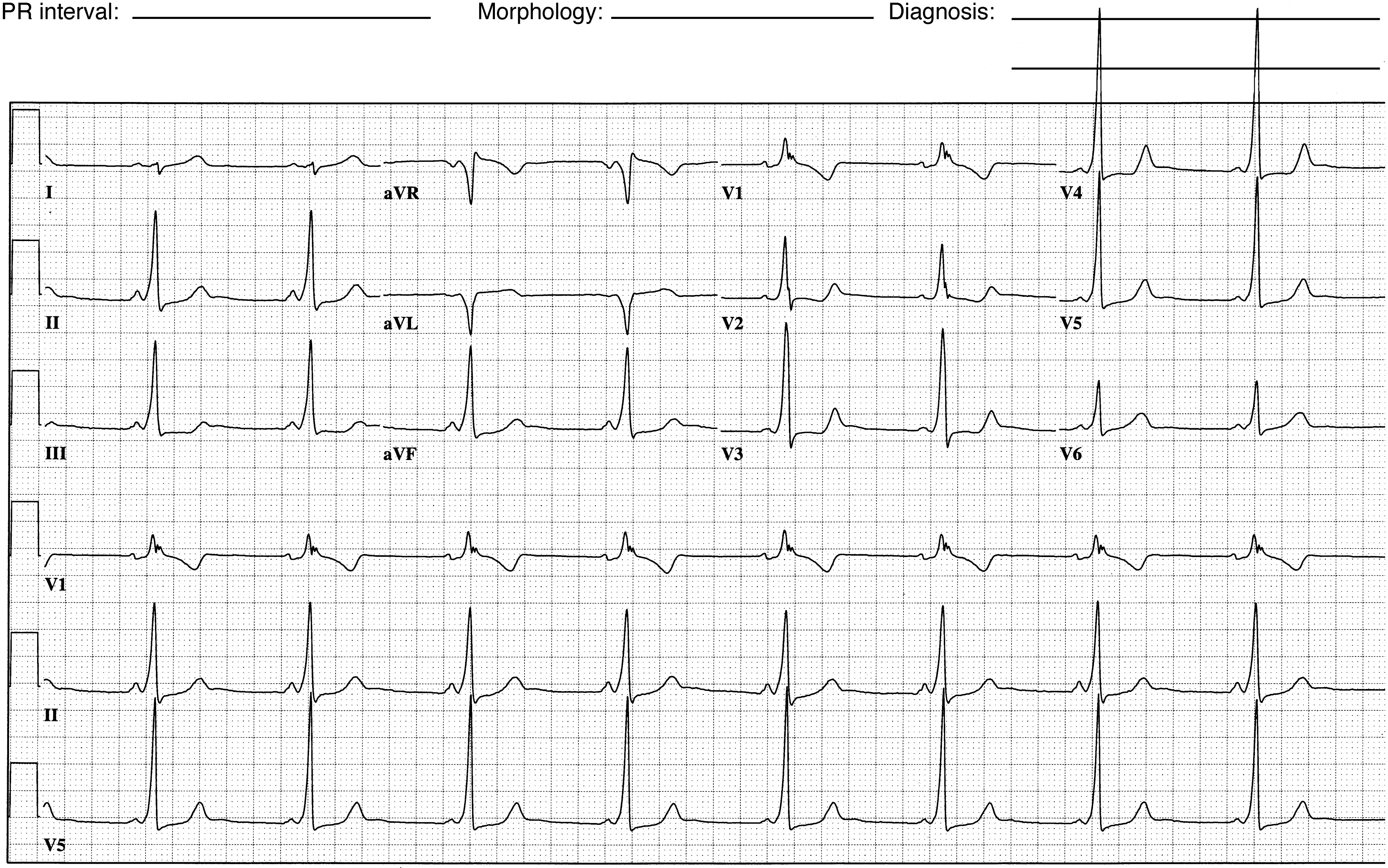
Atrial rate: ____________ QRS complex: ST segment: ____________

Ventricular rate: ____________ Axis: ____________ T wave: ____________

Rhythm: ____________ Duration: ____________ QT interval: ____________

P wave: ____________ Voltage: ____________ U wave: ____________

PR interval: ____________ Morphology: ____________ Diagnosis: ____________



ECG 2

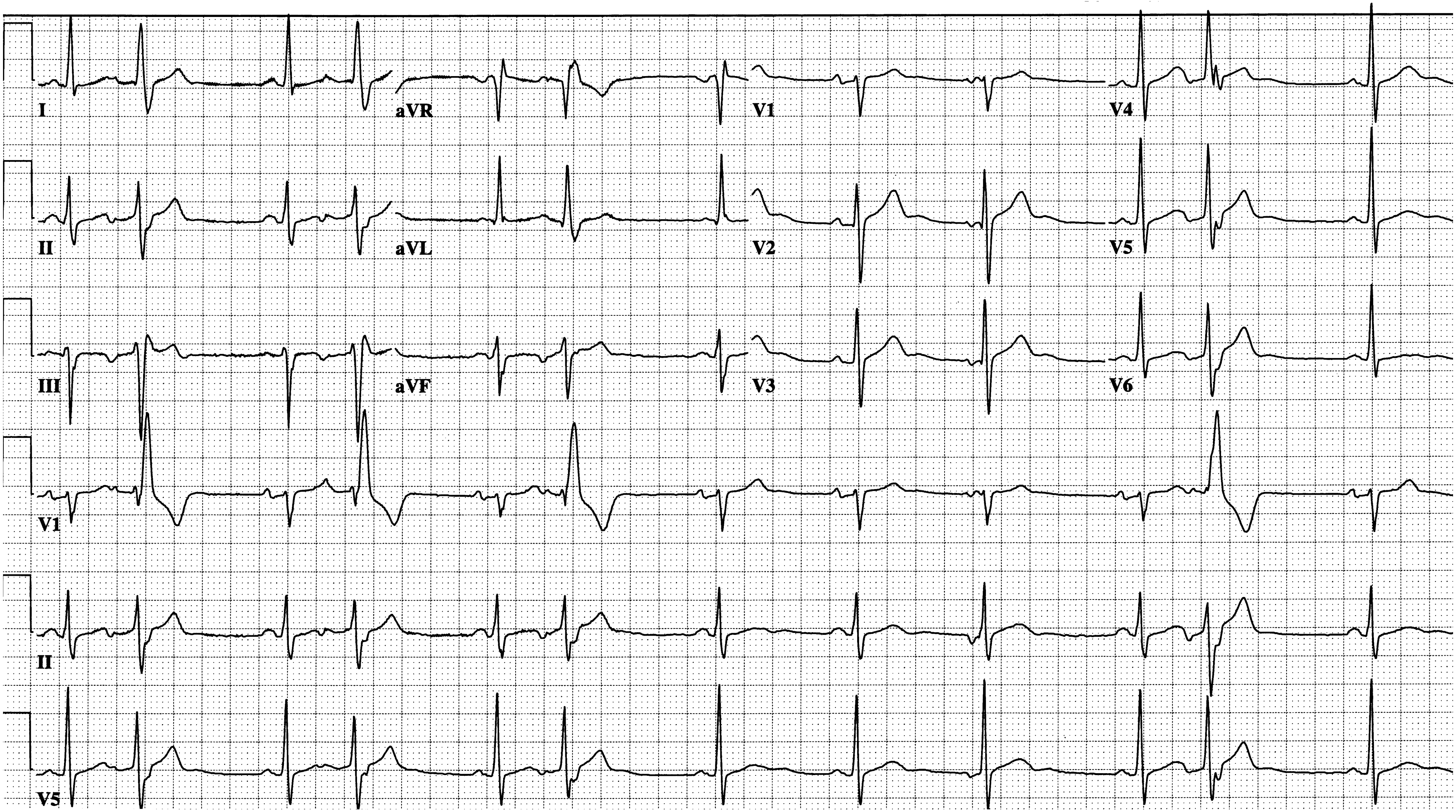
Atrial rate: ____________________ QRS complex: ST segment: ____________________

Ventricular rate: ____________________ Axis: ____________________ T wave: ____________________

Rhythm: ____________________ Duration: ____________________ QT interval: ____________________

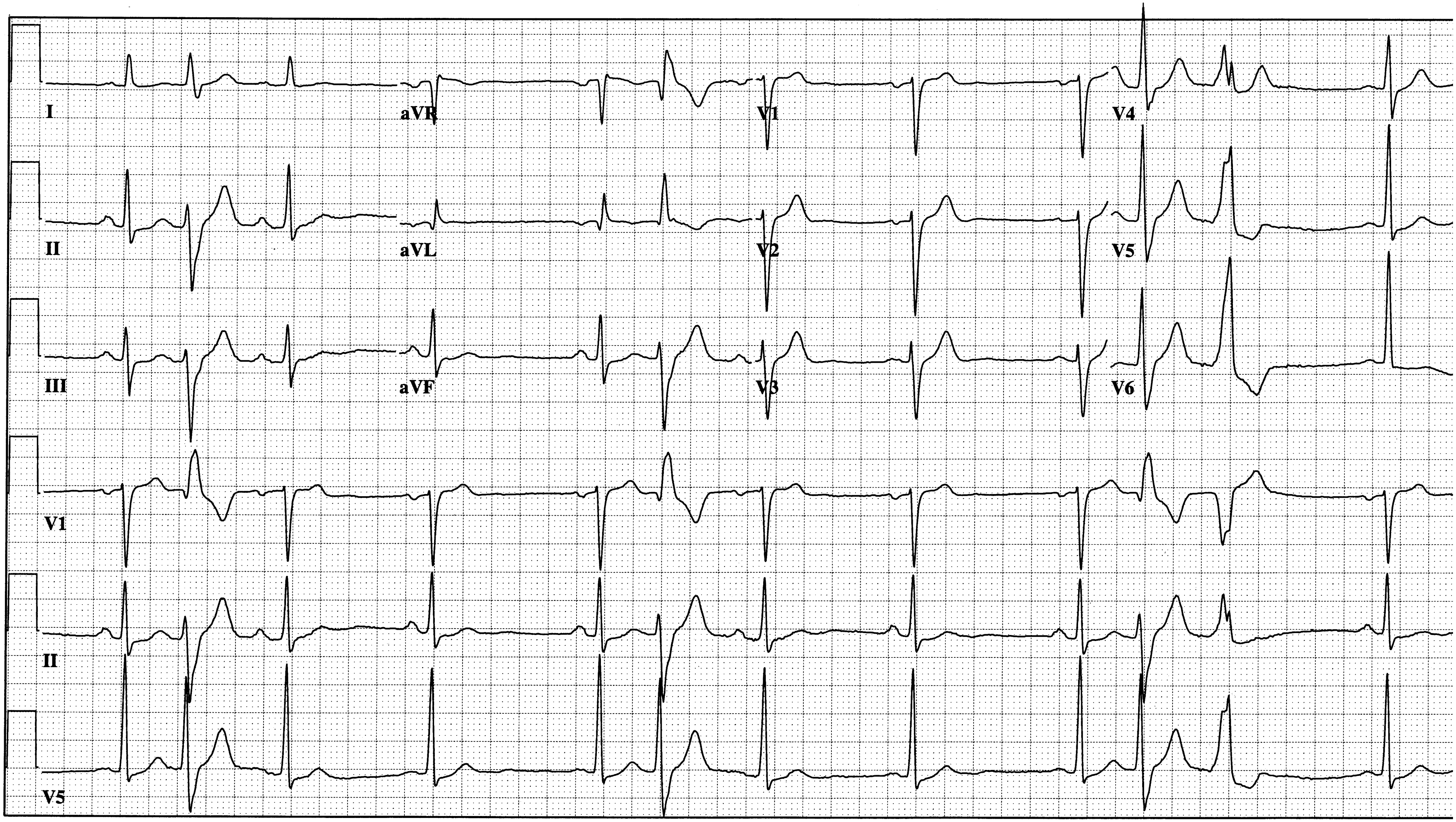
P wave: ____________________ Voltage: ____________________ U wave: ____________________

PR interval: ____________________ Morphology: ____________________ Diagnosis: ____________________



ECG 3

Atrial rate: ________	QRS complex:	ST segment: ________
Ventricular rate: ________	Axis: ________	T wave: ________
Rhythm: ________	Duration: ________	QT interval: ________
P wave: ________	Voltage: ________	U wave: ________
PR interval: ________	Morphology: ________	Diagnosis: ________
		________



ECG 4

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

ST segment: ______

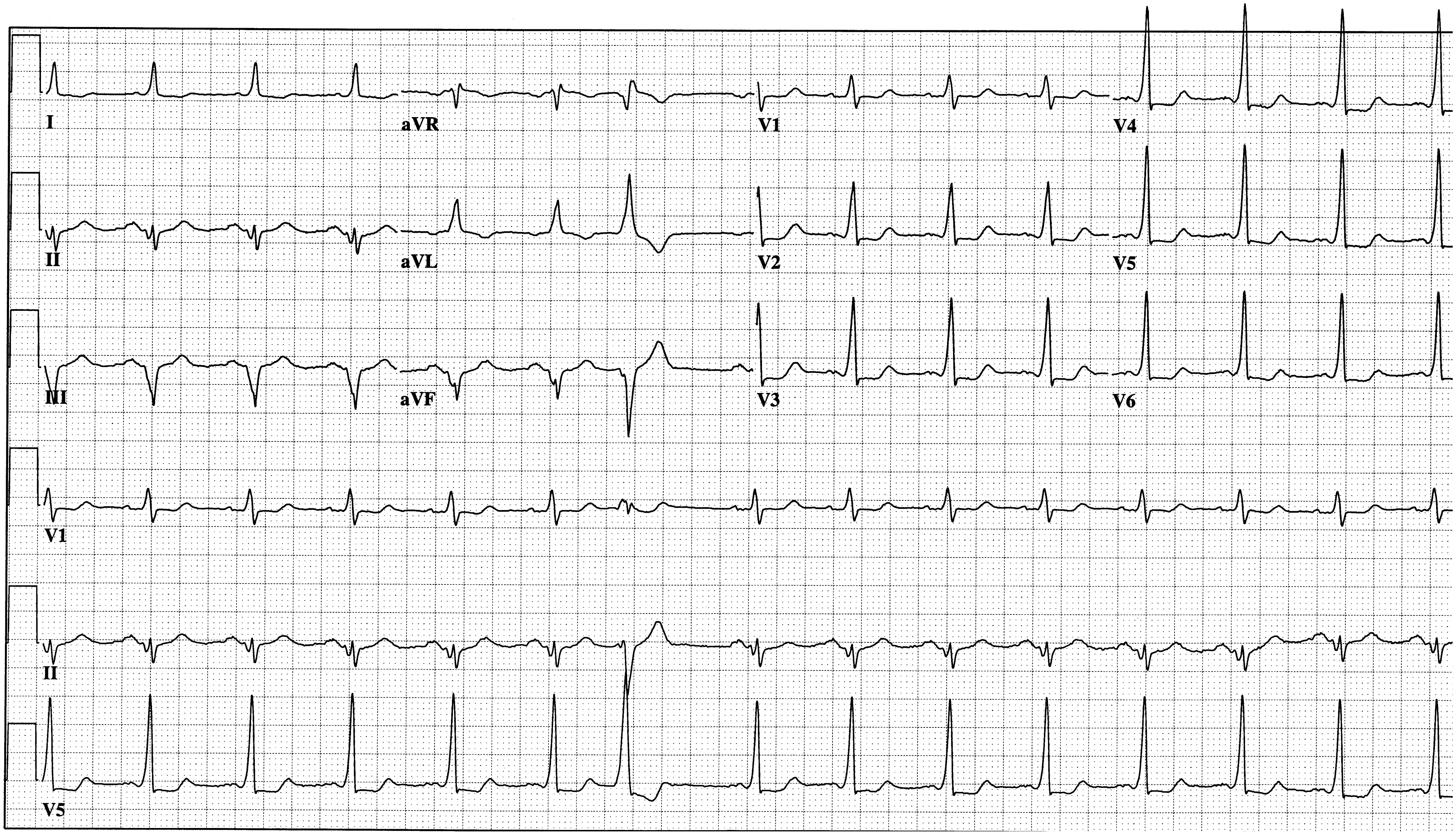
T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______

______



ECG 5

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

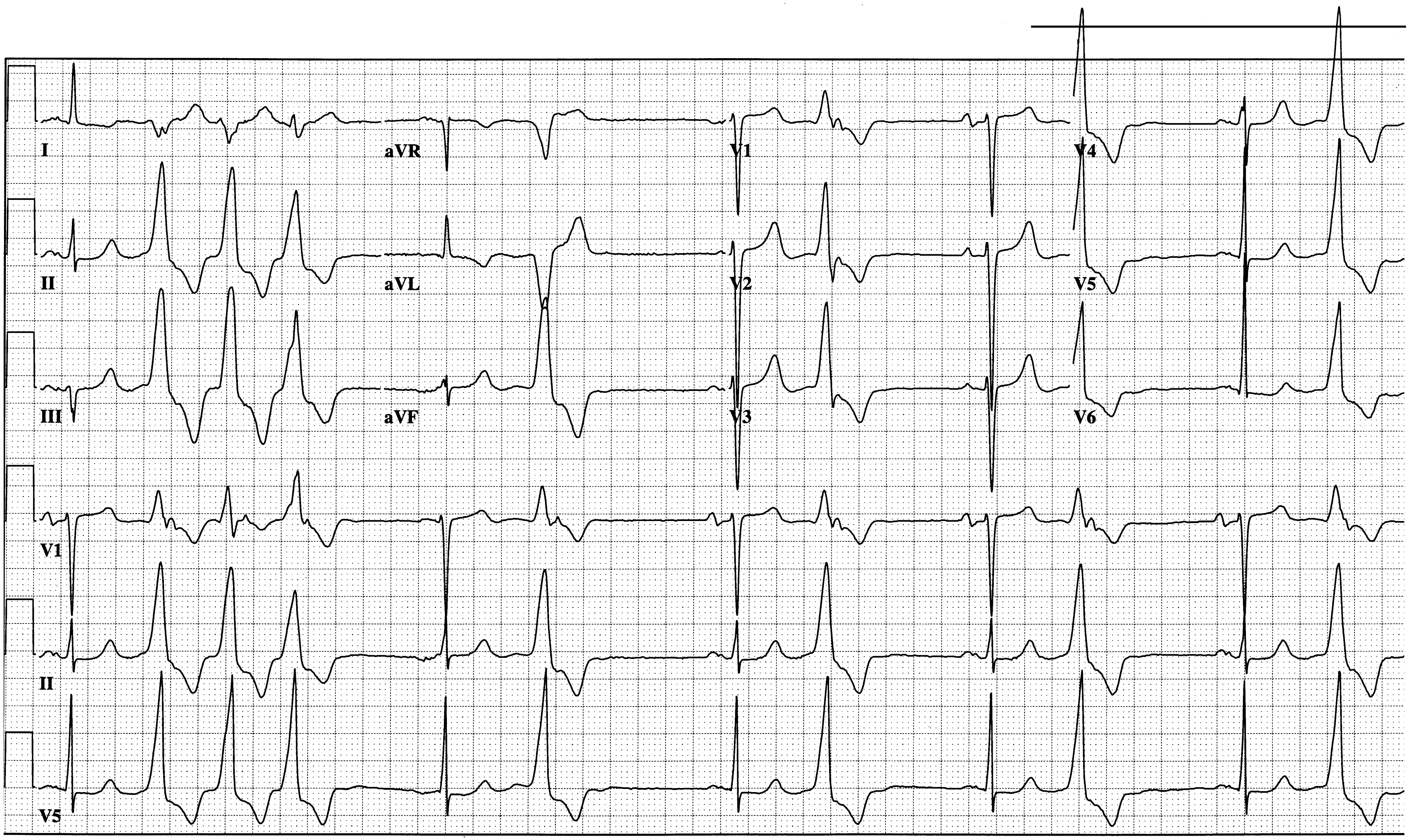
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 6

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

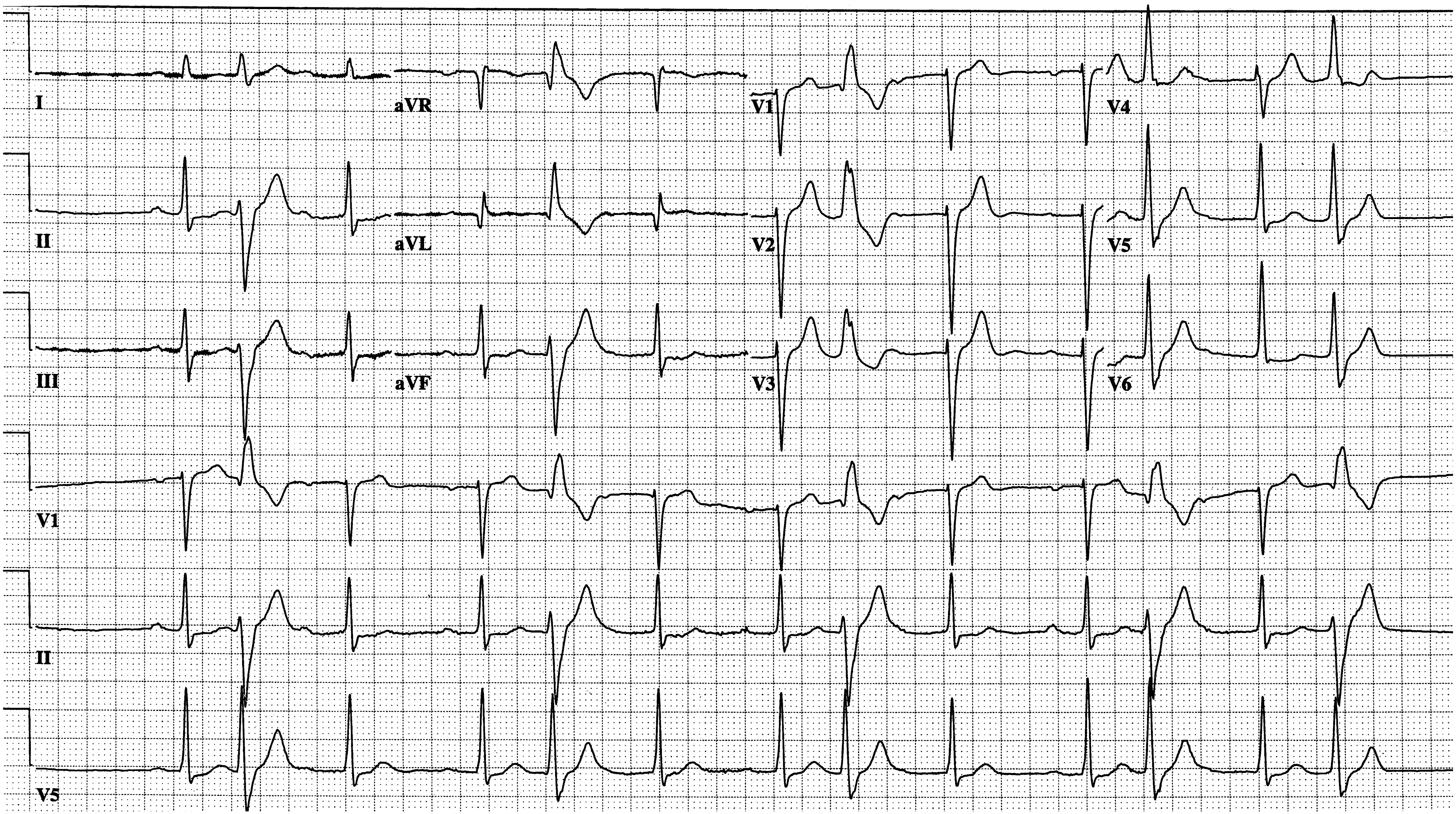
ST segment: ______________________

T wave: ______________________

QT interval: ______________________

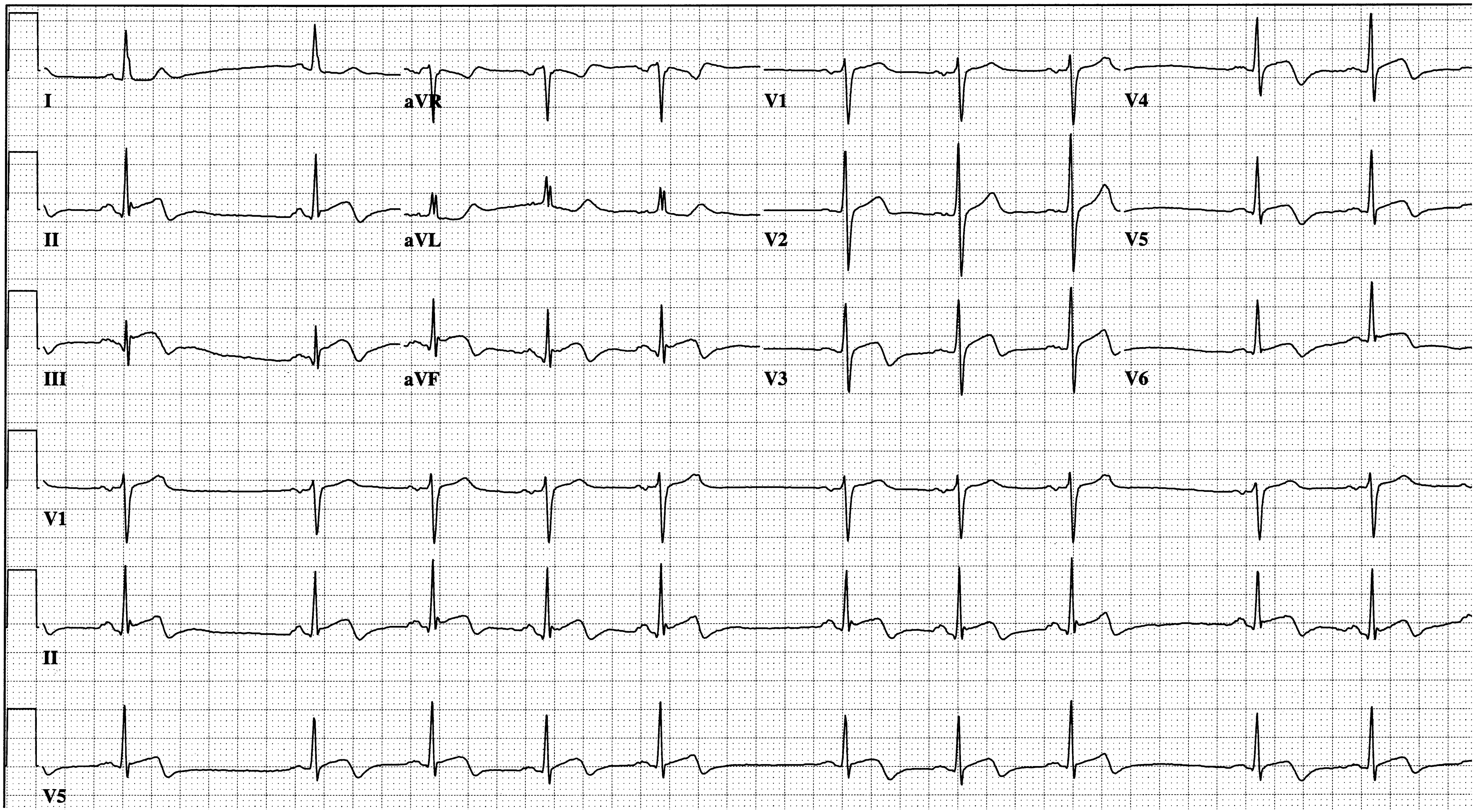
U wave: ______________________

Diagnosis: ______________________



ECG 7

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG 8

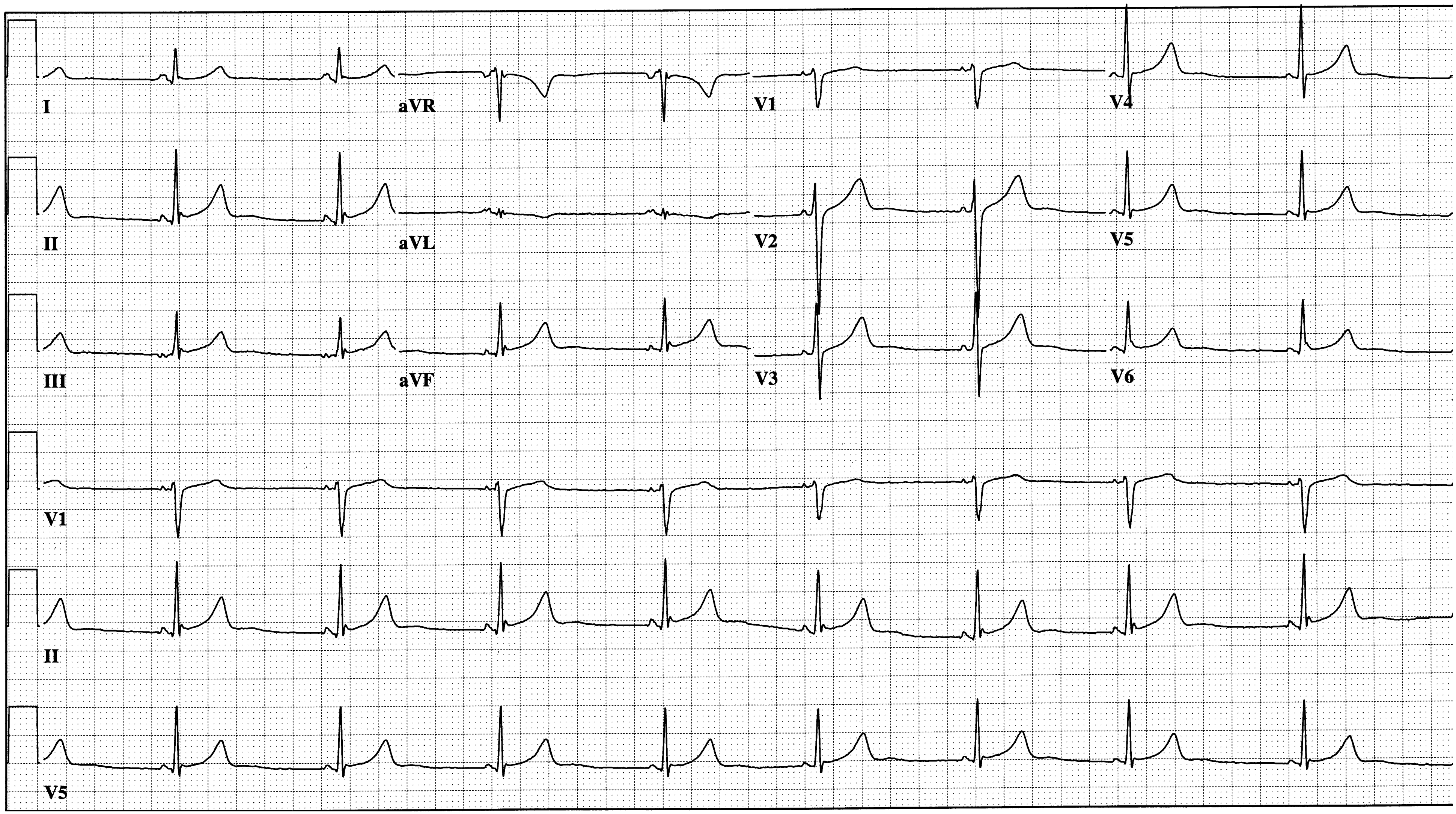
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG 9

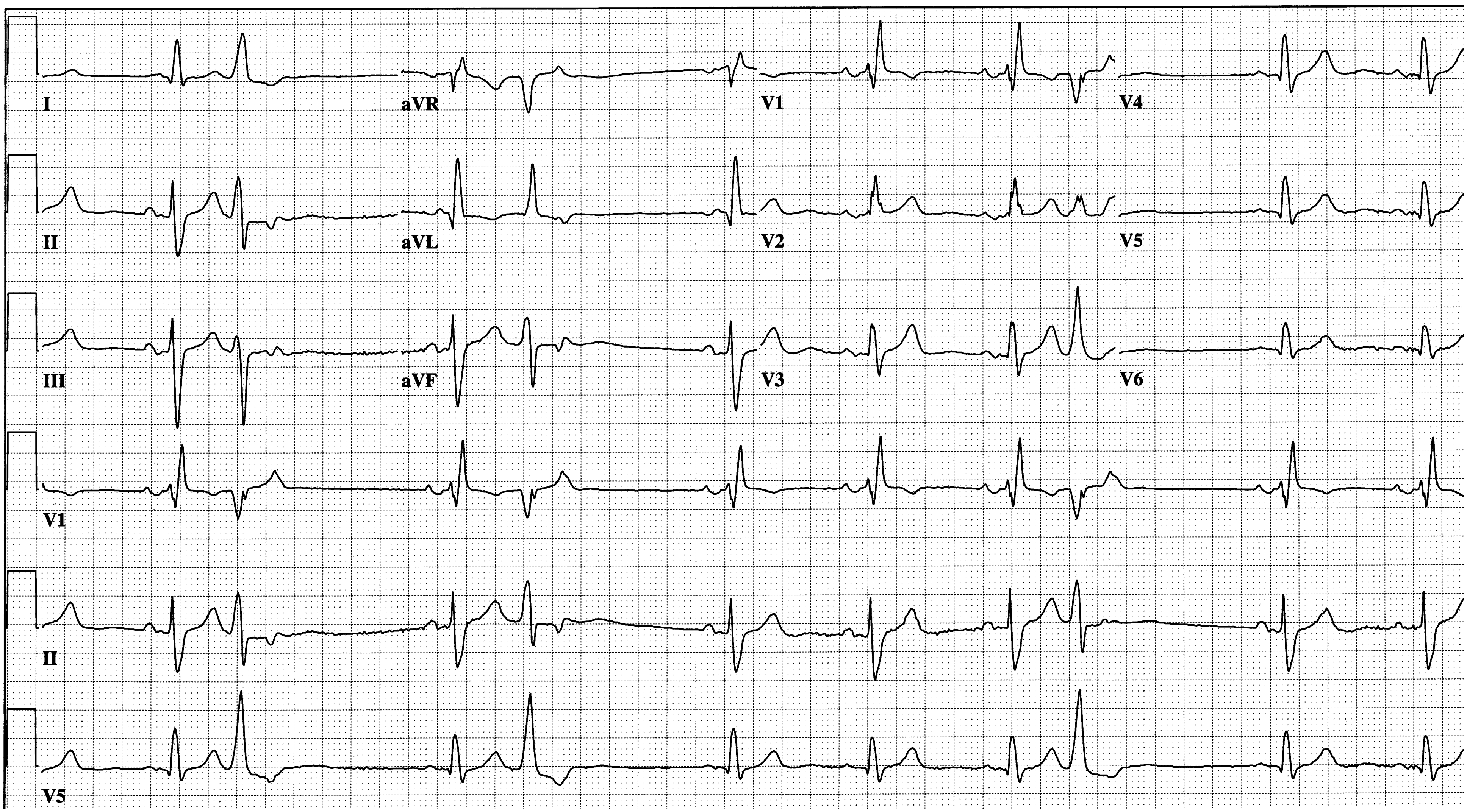
Atrial rate: ______________________ QRS complex: ST segment: ______________________

Ventricular rate: ______________________ Axis: ______________________ T wave: ______________________

Rhythm: ______________________ Duration: ______________________ QT interval: ______________________

P wave: ______________________ Voltage: ______________________ U wave: ______________________

PR interval: ______________________ Morphology: ______________________ Diagnosis: ______________________



ECG 10

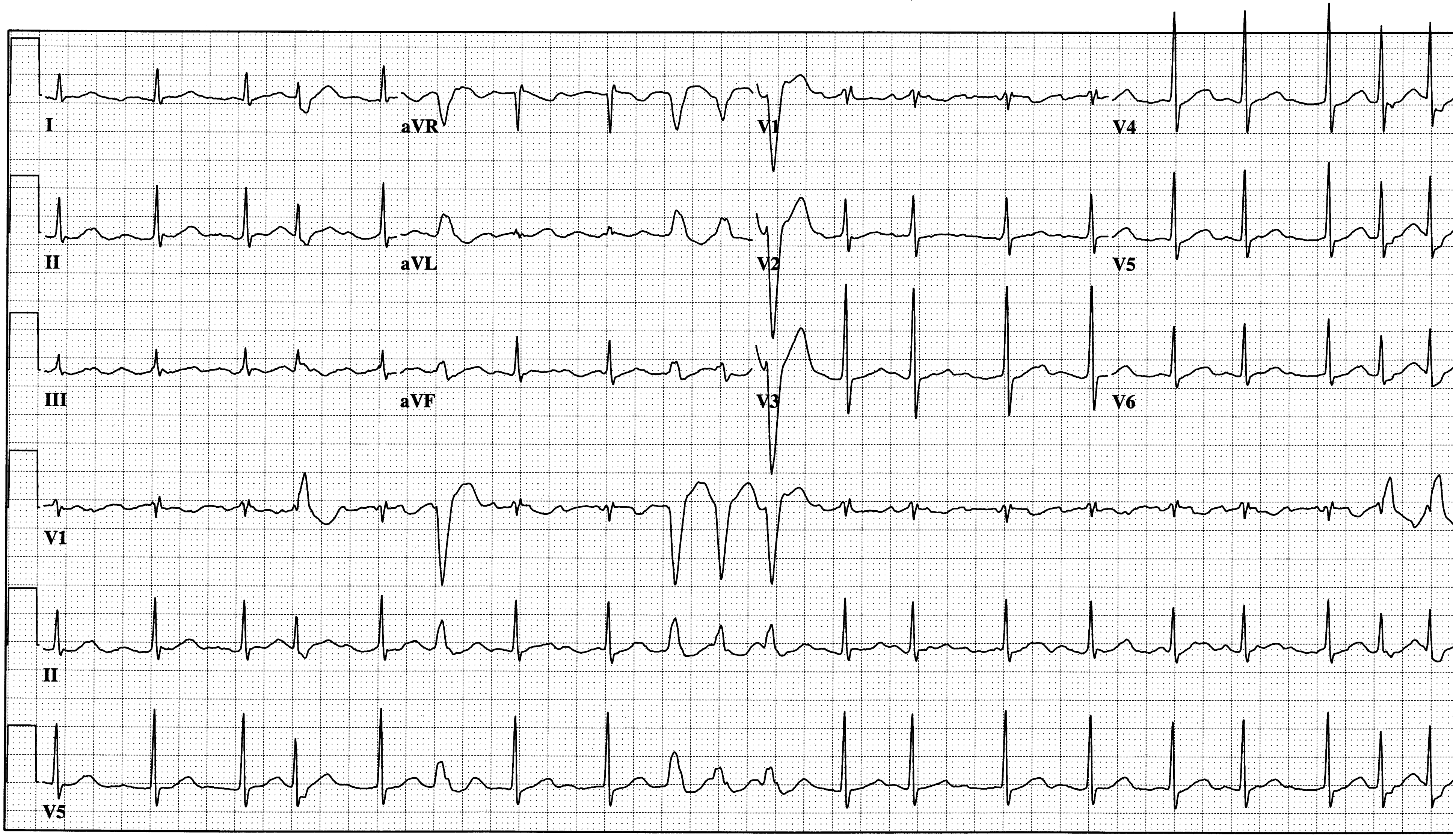
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG 11

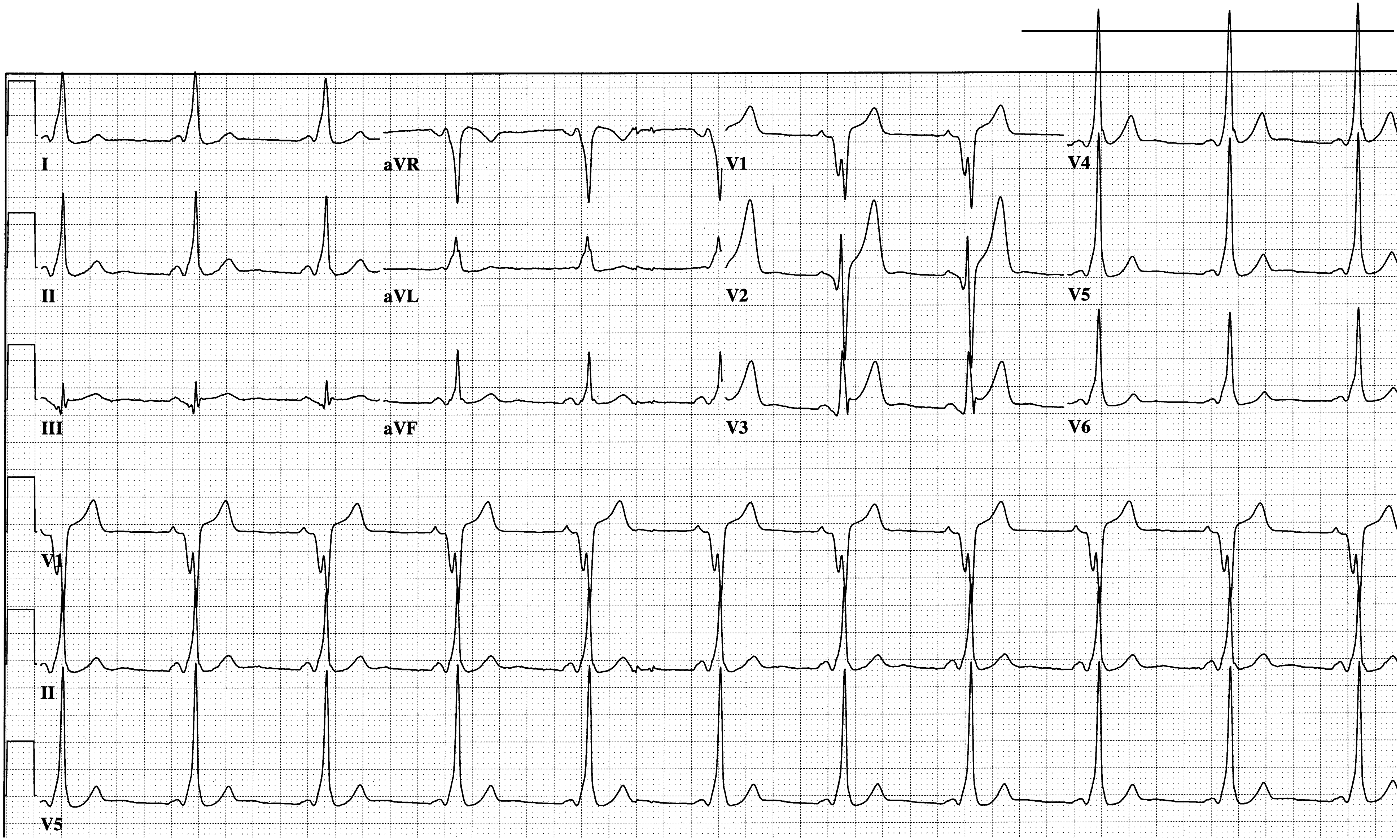
Atrial rate: ______________________ QRS complex: ST segment: ______________________

Ventricular rate: ______________________ Axis: ______________________ T wave: ______________________

Rhythm: ______________________ Duration: ______________________ QT interval: ______________________

P wave: ______________________ Voltage: ______________________ U wave: ______________________

PR interval: ______________________ Morphology: ______________________ Diagnosis: ______________________



ECG 12

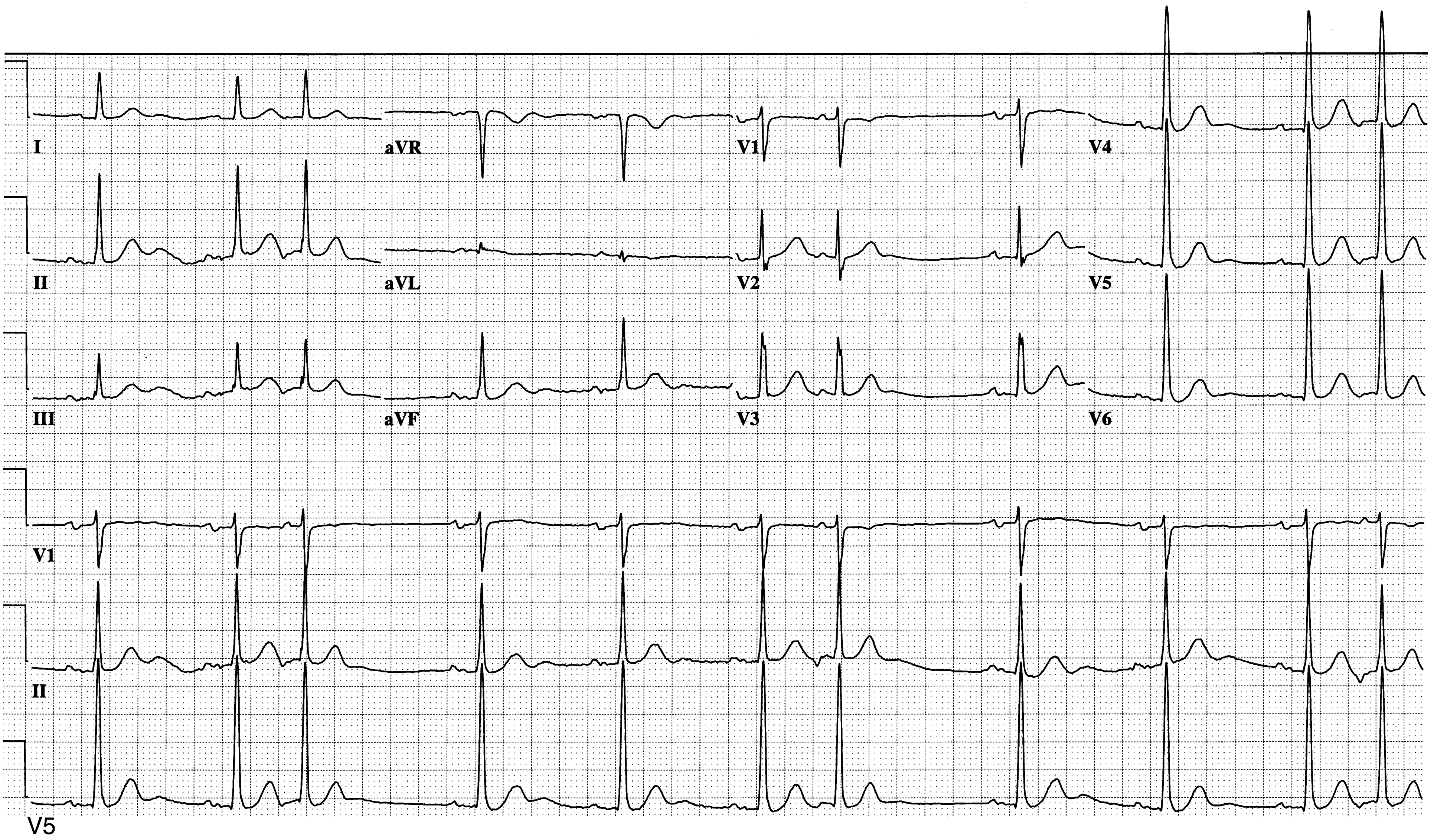
Atrial rate: ______________ QRS complex: ST segment: ______________

Ventricular rate: ______________ Axis: ______________ T wave: ______________

Rhythm: ______________ Duration: ______________ QT interval: ______________

P wave: ______________ Voltage: ______________ U wave: ______________

PR interval: ______________ Morphology: ______________ Diagnosis: ______________



ECG 13

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

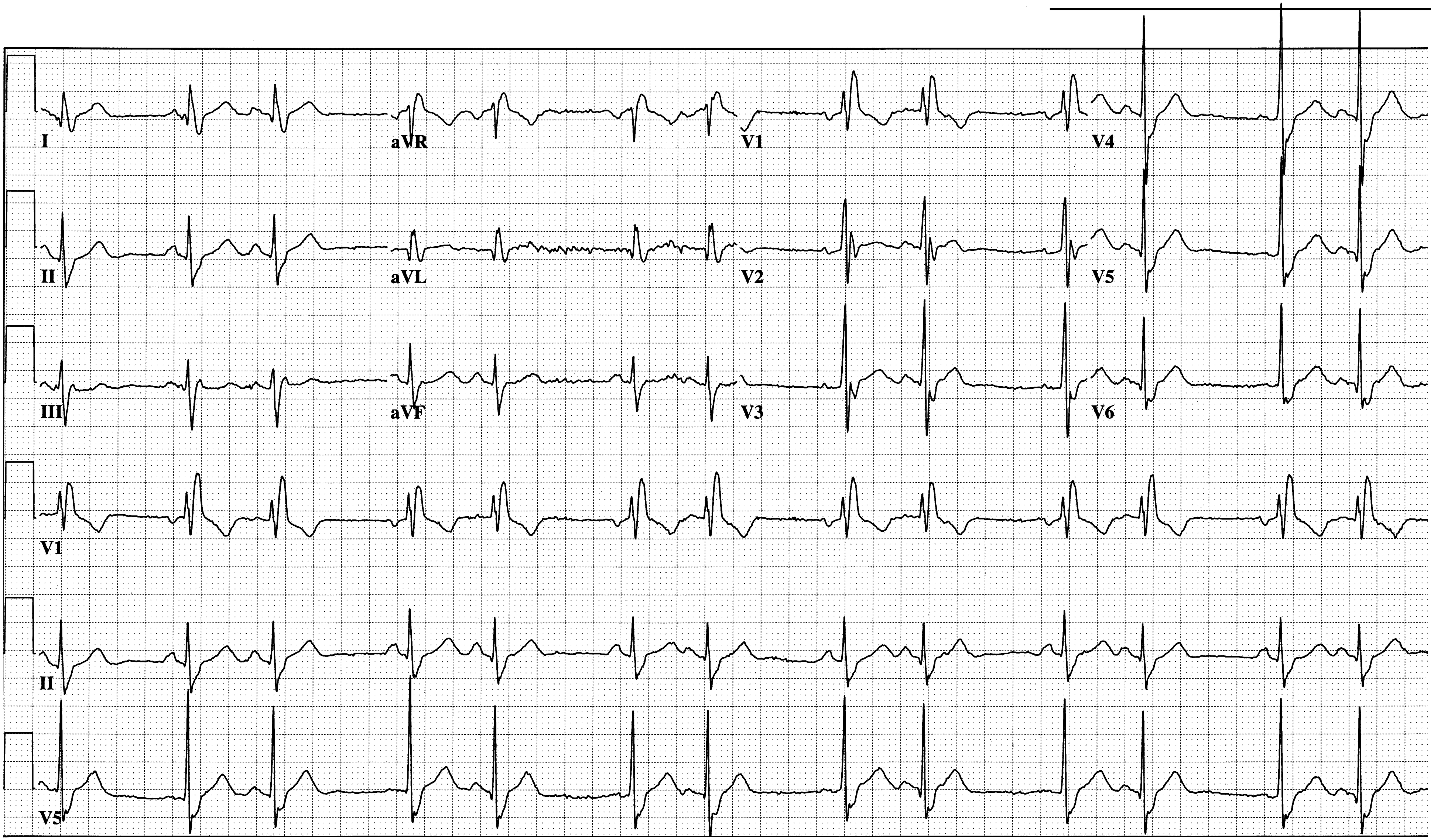
ST segment: ______________________

T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________



ECG 14

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

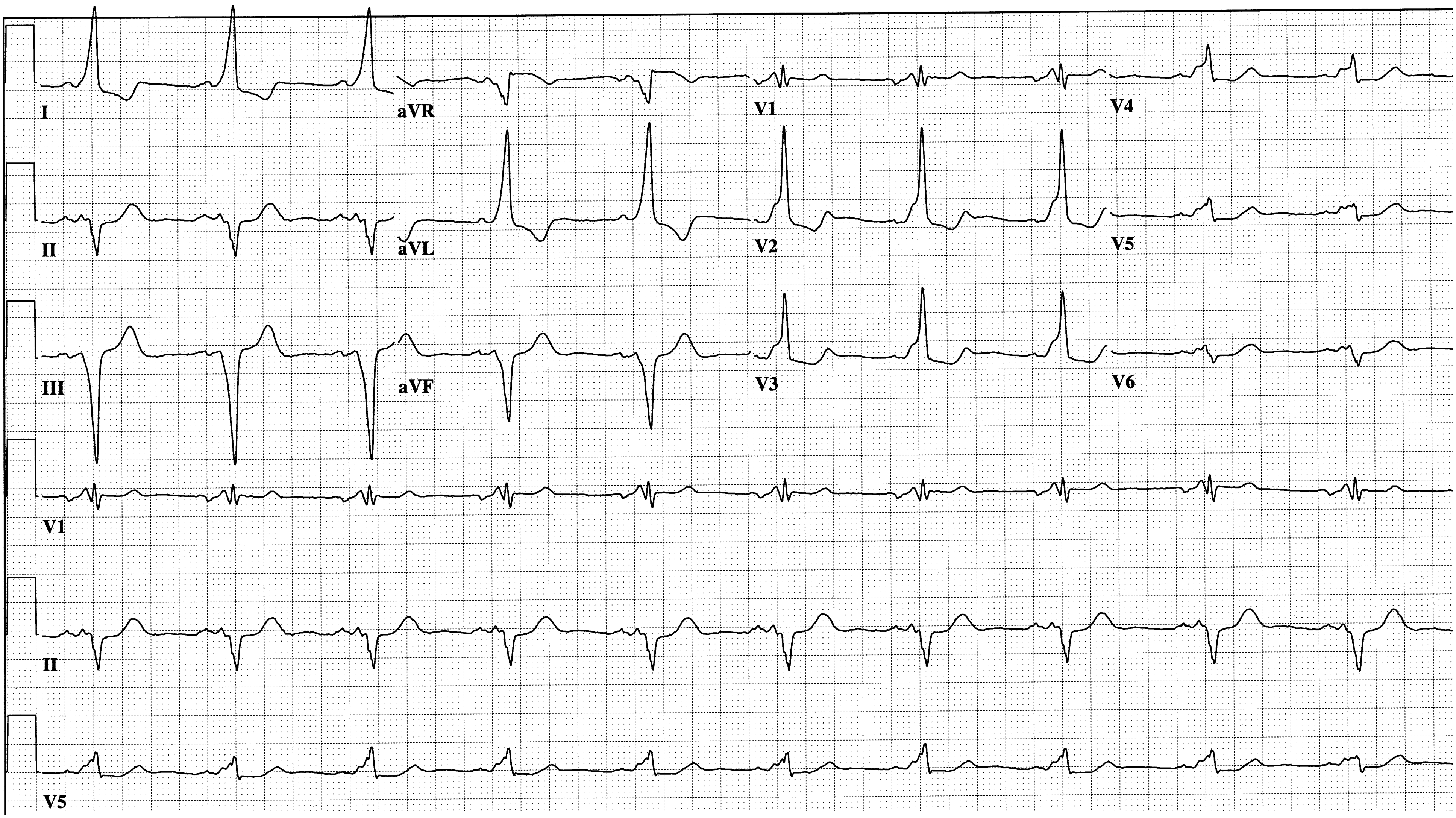
ST segment: ______

T wave: ______

QT interval: ______

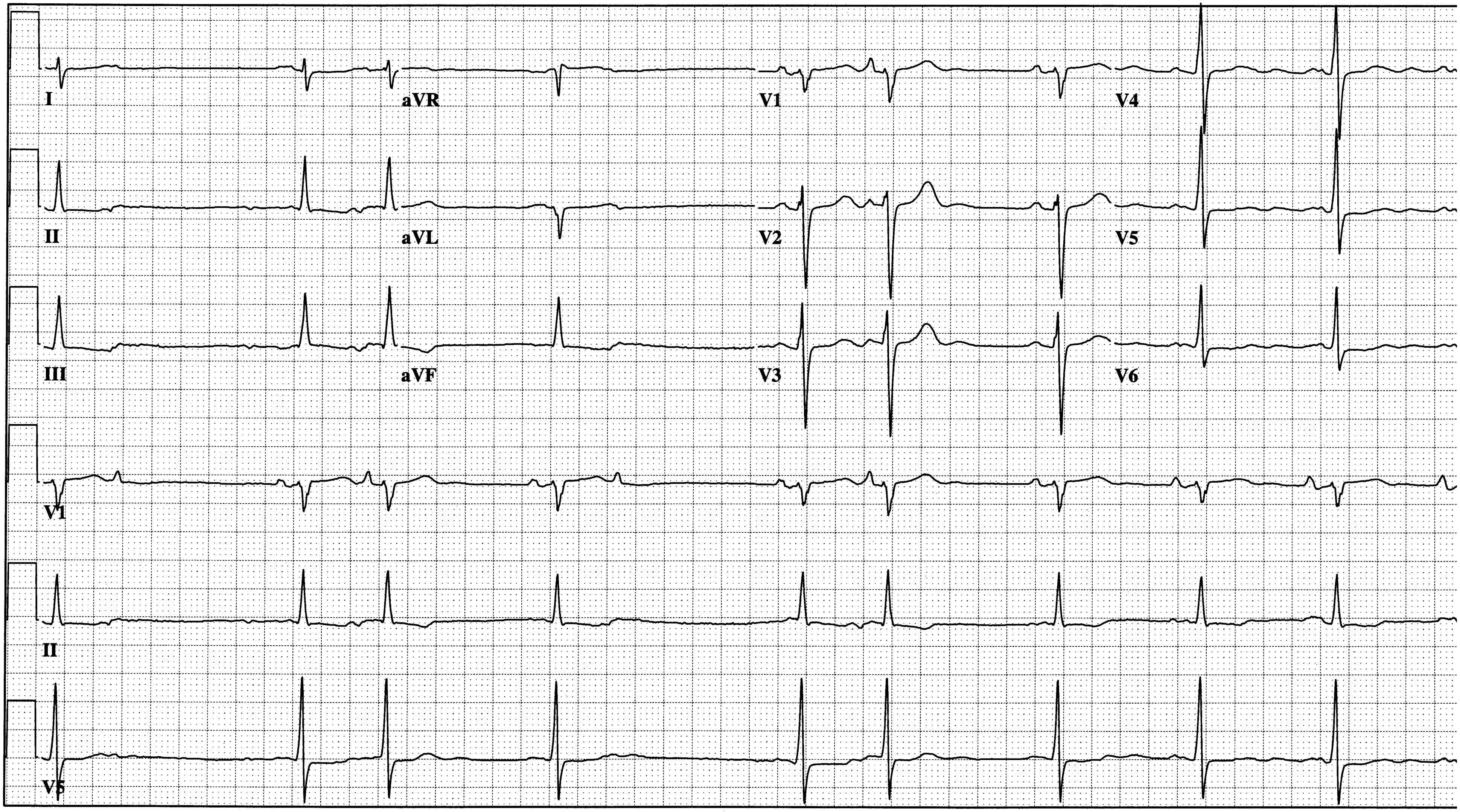
U wave: ______

Diagnosis: ______



ECG 15

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG 16

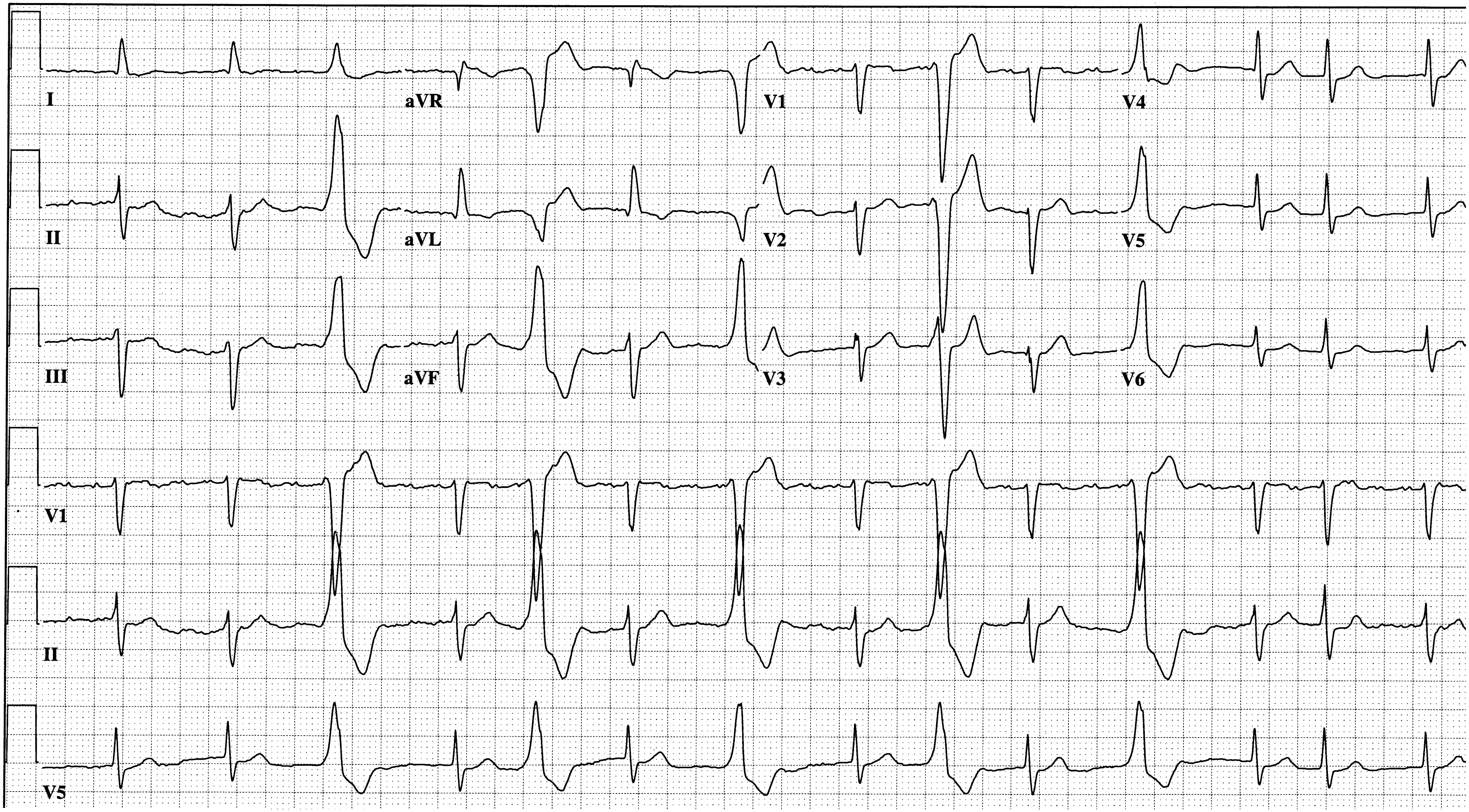
Atrial rate: ______________________ QRS complex: ST segment: ______________________

Ventricular rate: ______________________ Axis: ______________________ T wave: ______________________

Rhythm: ______________________ Duration: ______________________ QT interval: ______________________

P wave: ______________________ Voltage: ______________________ U wave: ______________________

PR interval: ______________________ Morphology: ______________________ Diagnosis: ______________________



ECG 17

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

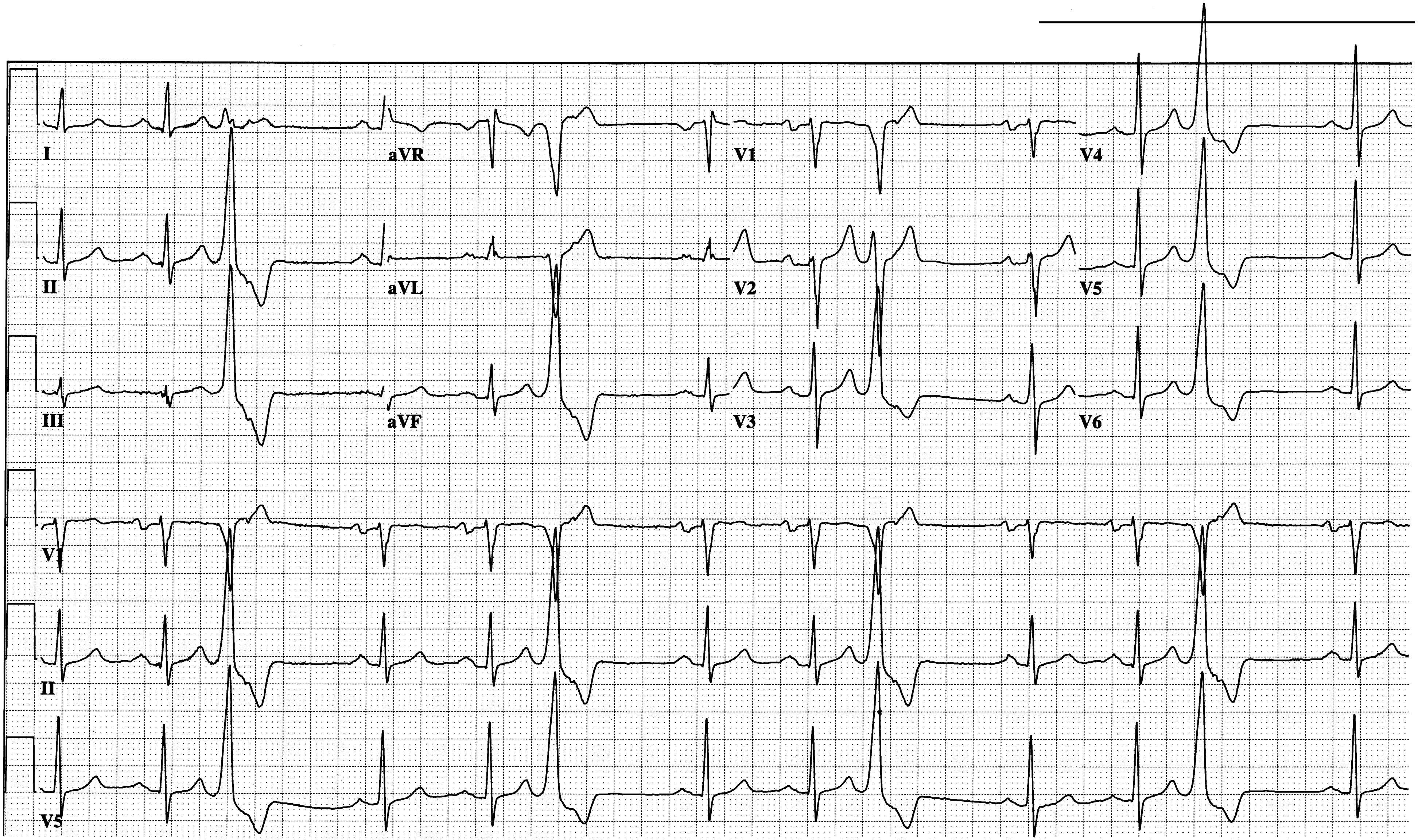
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 18

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

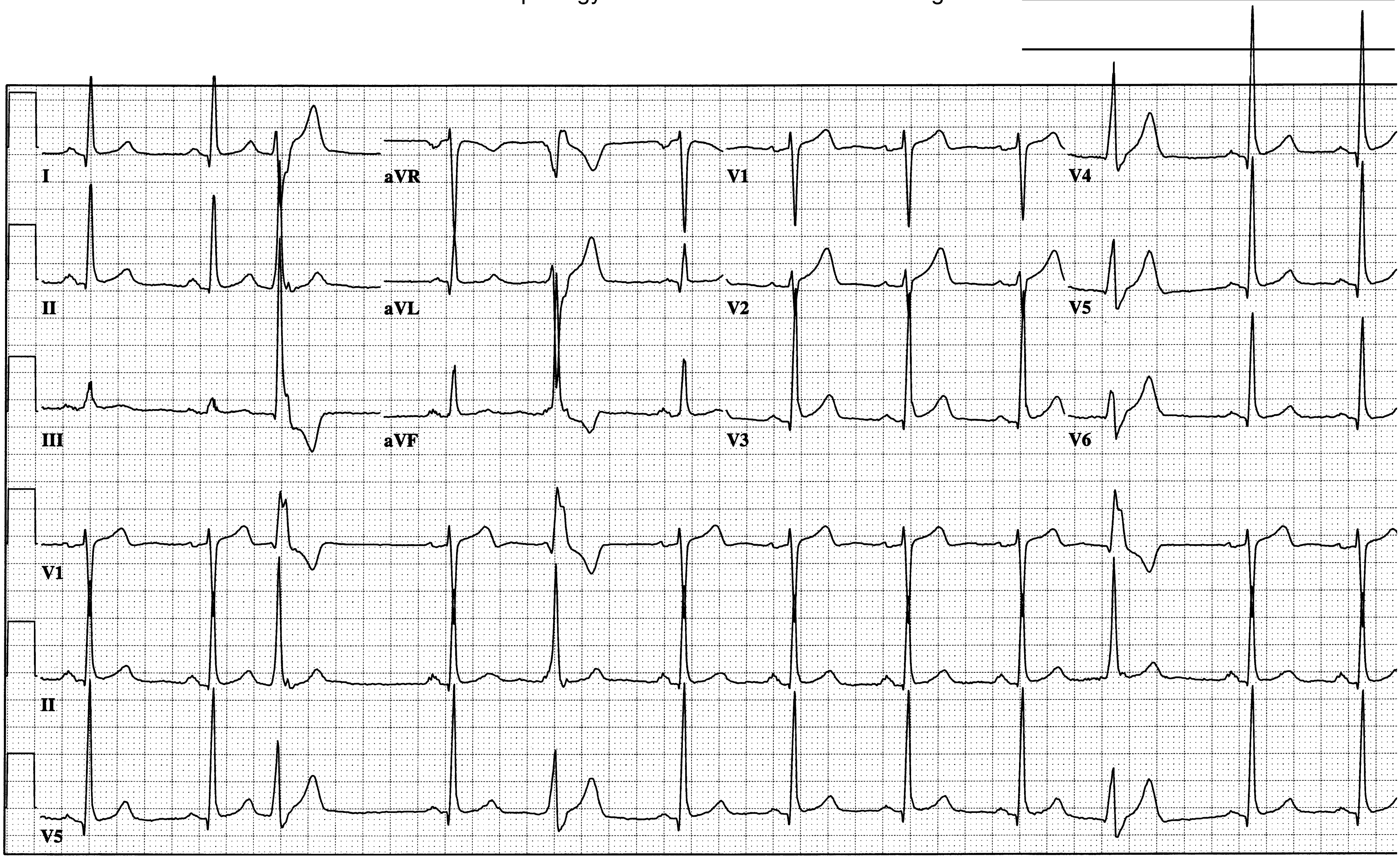
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG 19

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

ST segment: ____________________

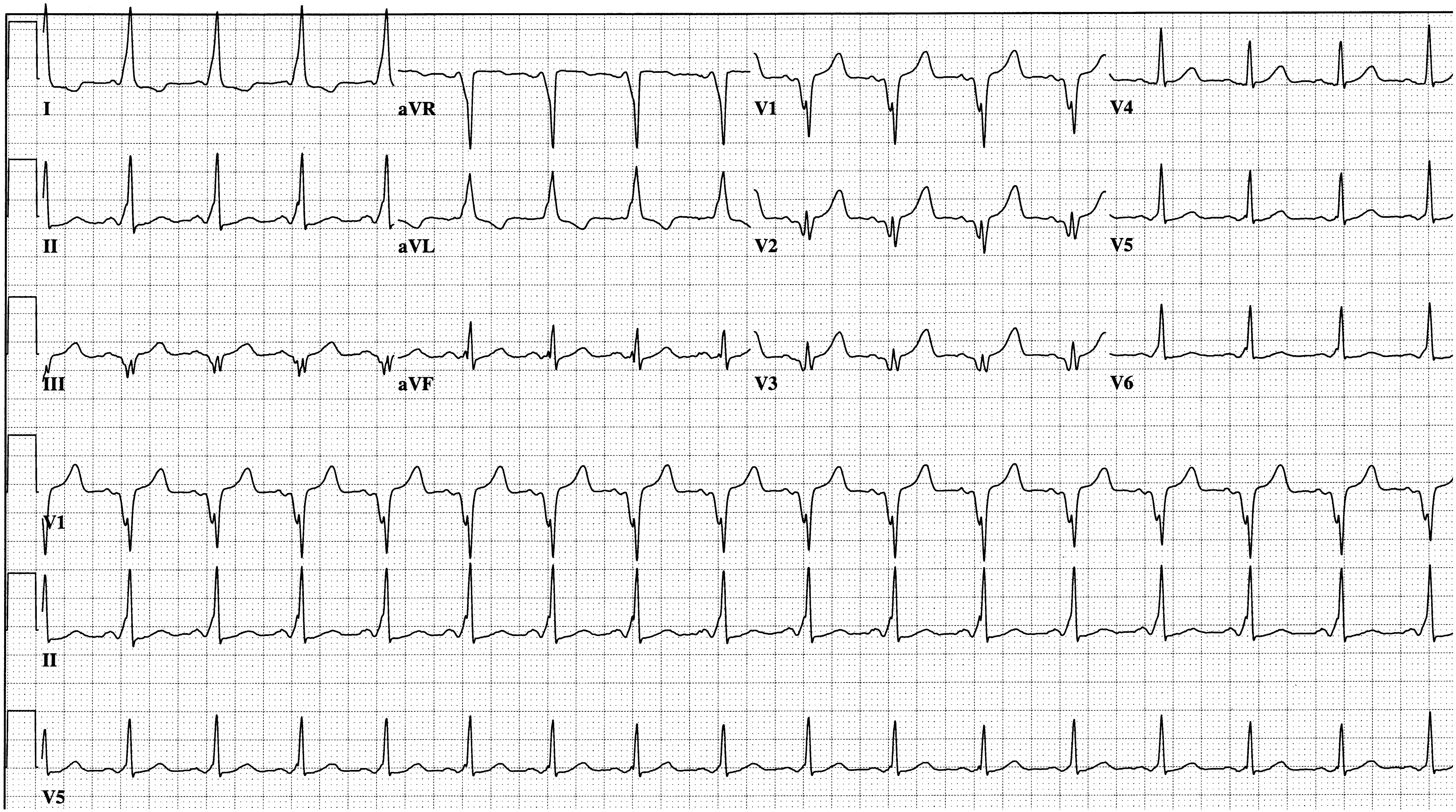
T wave: ____________________

QT interval: ____________________

U wave: ____________________

Diagnosis: ____________________

____



ECG 20

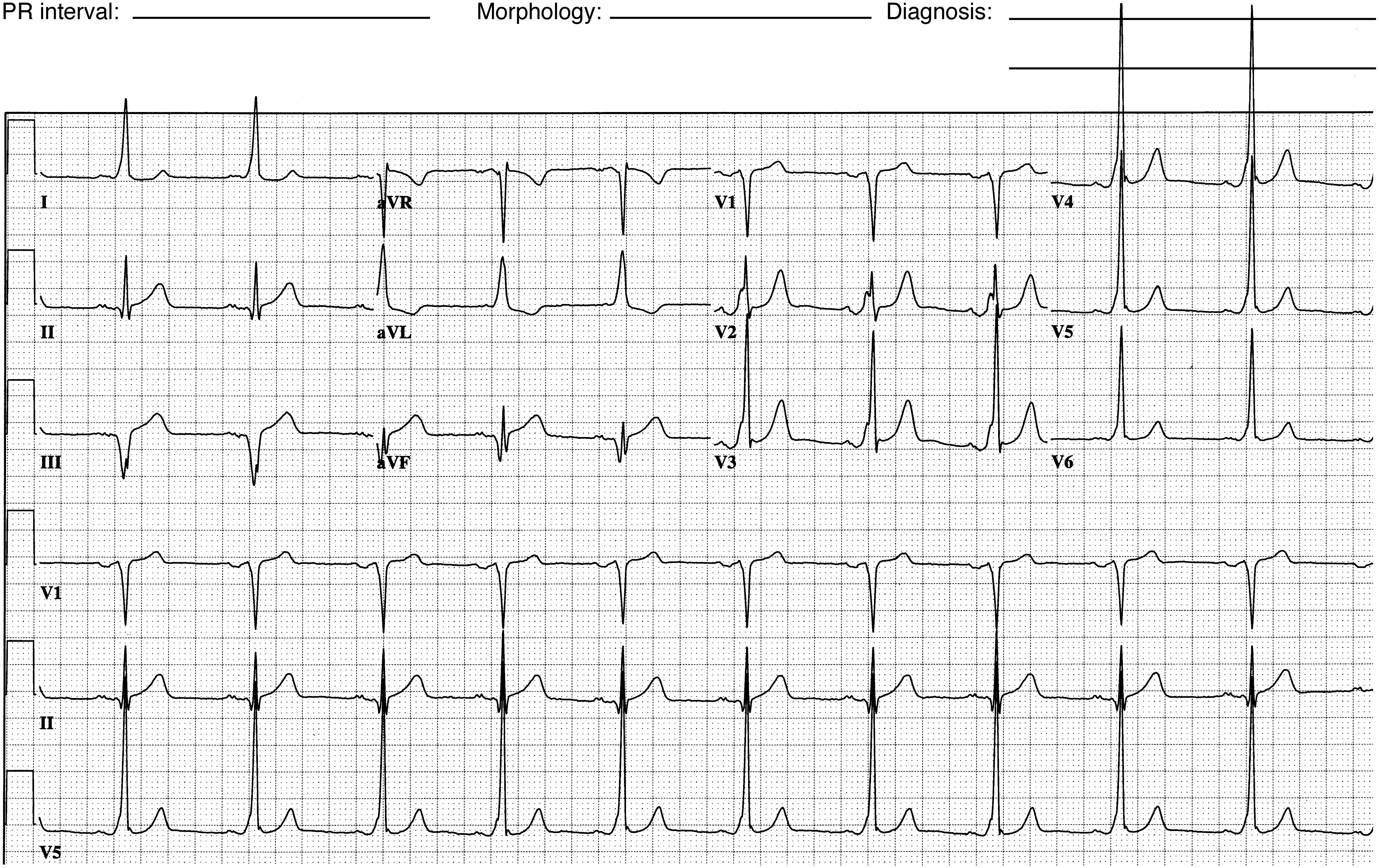
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



Extrasystoles and Preexcitation Syndromes

Interpretations of Sample Tracings

ECG 1

Atrial rate: 50
Ventricular rate: 50
Rhythm: Sinus bradycardia
P wave: Normal
PR interval: 110 msec
QRS complex:
  Axis: 90°
  Duration: 140 msec
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval: 510 msec
U wave:
Diagnosis: Sinus bradycardia with WPW. It is inappropriate to consider the diagnosis of a lateral MI, even though there is a prominent Q wave in aVL, in the presence of WPW.

ECG 2

Atrial rate: 72
Ventricular rate: 72
Rhythm: Sinus rhythm with frequent PACs
P wave: Normal
PR interval: 140 msec
QRS complex:
  Axis: −20°
  Duration: 100 msec
  Voltage: Increased in I
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 420 msec
U wave:
Diagnosis: Sinus rhythm with frequent PACs with aberrant conduction and possible LVH by voltage criteria. The premature beats might at first be mistaken for PVCs, but they are all preceded by a P wave.

ECG 3

Atrial rate: 55
Ventricular rate: 75
Rhythm: Sinus rhythm with frequent PVCs
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: 45°
  Duration: 100 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 360 msec
U wave:
Diagnosis: Sinus bradycardia with frequent PVCs. Two of the PVCs are "interpolated", meaning that they do not reset the sinus rate.

ECG 4

Atrial rate: 85
Ventricular rate: 85
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: −45°
  Duration: 110 msec
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval: 380 msec
U wave:
Diagnosis: Sinus rhythm with WPW

ECG 5

Atrial rate: 45
Ventricular rate: 70
Rhythm: Sinus bradycardia with frequent and consecutive PVCs
P wave: Normal
PR interval: 200 msec
QRS complex:

Axis: 0°
Duration: 90 msec
Voltage: Increased in the precordial leads
Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 420 msec
U wave:
Diagnosis: Sinus bradycardia with frequent and consecutive PVCs. AV dissociation can be seen in the V_1 rhythm strip during the successive PVCs. There is also voltage criteria for LVH.

ECG 6

Atrial rate: 60
Ventricular rate: 90
Rhythm: Sinus rhythm with first degree AV block and frequent PVCs
P wave: Normal
PR interval: 240 msec
QRS complex:
Axis: 60°
Duration: 105 msec
Voltage: Normal
Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 370 msec
U wave:
Diagnosis: Sinus rhythm with frequent PVCs. After the PVCs, the succeeding PR interval is prolonged, a phenomenon known as concealed retrograde conduction. The prolongation of the PR interval is caused by retrograde depolarization of the AV node by the PVCs. This depolarization can only be detected by the prolongation of the next PR interval, thus the term concealed.

ECG 7

Atrial rate: 60
Ventricular rate: 60
Rhythm: Sinus rhythm with nonconducted PACs
P wave: Normal
PR interval: 160 msec
QRS complex:
Axis: 45°
Duration: 90 msec
Voltage: Normal
Morphology: Normal
ST segment: Diffuse ST segment elevation in II, III, aVF, and V_2 to V_6

T wave: Diffuse T wave inversion
QT interval: 380 msec
U wave:
Diagnosis: Sinus rhythm with blocked PACs and ST segment changes consistent with an acute inferior and anterolateral MI. Whenever there is a pause on an ECG, one should look for P waves, typically superimposed on the T wave before the pause.

ECG 8

Atrial rate: 52
Ventricular rate: 52
Rhythm: Sinus bradycardia
P wave: Normal
PR interval: 100 msec
QRS complex:
  Axis: 60°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 450 msec
U wave:
Diagnosis: Sinus bradycardia with a short PR interval. Without any documented arrhythmias, the short PR interval should be considered to be a normal variant.

ECG 9

Atrial rate: 60
Ventricular rate: 60
Rhythm: Sinus rhythm with frequent PVCs
P wave: Normal
PR interval: 180 msec
QRS complex:
  Axis: −40°
  Duration: 135 msec, RBBB
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 420 msec
U wave:
Diagnosis: Sinus rhythm with frequent PVCs, left axis deviation and RBBB. The monomorphic PVCs are typical, in that they have a fixed coupling interval.

ECG 10

Atrial rate:
Ventricular rate: 118
Rhythm: Atrial fibrillation with rapid ventricular response
P wave:
PR interval:
QRS complex:
 Axis: 60°
 Duration: 80 msec
 Voltage: Normal
 Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 340 msec
U wave:
Diagnosis: Atrial fibrillation with rapid ventricular response. The wide beats are probably supraventricular with aberrant conduction, but this cannot be stated with any certainty in atrial fibrillation.

ECG 11

Atrial rate: 65
Ventricular rate: 65
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 120 msec
QRS complex:
 Axis: 45°
 Duration: 130 msec
 Voltage:
 Morphology:
ST segment:
T wave:
QT interval: 400 msec
U wave:
Diagnosis: Sinus rhythm with WPW

ECG 12

Atrial rate: 65
Ventricular rate: 65
Rhythm: Sinus rhythm with frequent PACs
P wave: Normal
PR interval: 200 msec
QRS complex:

Axis: 60°
Duration: 100 msec
Voltage: Increased in the precordial leads
Morphology: Normal
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 380 msec
U wave: Prominent U waves in I, II, III, and aVF
Diagnosis: Sinus rhythm with frequent PACs and borderline criteria for LVH in V_5

ECG 13

Atrial rate: 77
Ventricular rate: 77
Rhythm: Sinus rhythm with regular PACs
P wave: Normal
PR interval: 140 msec
QRS complex:
Axis: −10°
Duration: 135 msec, RBBB
Voltage: Normal
Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 400 msec
U wave:
Diagnosis: Sinus rhythm with regular PACs and RBBB

ECG 14

Atrial rate: 60
Ventricular rate: 60
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 120 msec
QRS complex:
Axis: −60°
Duration: 120 msec
Voltage:
Morphology:
ST segment:
T wave:
QT interval: 400 msec
U wave:
Diagnosis: Sinus rhythm with WPW. It would be inappropriate to diagnose LVH or previous MI from this ECG.

ECG 15

Atrial rate: 52
Ventricular rate: 52
Rhythm: Sinus bradycardia with occasional blocked PACs
P wave: Normal
PR interval: 180 msec
QRS complex:
  Axis: 100°
  Duration: 100 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 460 msec
U wave:
Diagnosis: Sinus bradycardia with frequent PACs, some nonconducted

ECG 16

Atrial rate: 300
Ventricular rate: 85
Rhythm: Atrial flutter with 4:1 AV block and ventricular parastystole
P wave:
PR interval:
QRS complex:
  Axis: −60°
  Duration: 110 msec, left anterior fascicular block (LAFB)
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Nonspecific changes
QT interval: 400 msec
U wave:
Diagnosis: Atrial flutter with 4:1 AV conduction, left axis deviation, left anterior fascicular block [left axis deviation greater that −45°, tiny Q waves in I and aVL, and a minor intraventricular conduction defect (IVCD)], and ventricular parasystole. Note that the ventricular beats do not have a fixed coupling interval but do have a fixed interectopic interval. The presence of a fusion beat with a morphology between that of the ventricular and supraventricular complexes towards the end of the tracing also supports this diagnosis.

ECG 17

Atrial rate: 75
Ventricular rate: 75
Rhythm: Sinus rhythm with frequent PVCs
P wave: possible left atrial abnormality
PR interval: 200 msec
QRS complex:
  Axis: 30°
  Duration: 100 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 380 msec
U wave:
Diagnosis: Sinus rhythm with frequent PVCs and possible left atrial abnormality. Note that the monomorphic PVCs have a typical fixed coupling interval.

ECG 18

Atrial rate: 75
Ventricular rate: 70
Rhythm: Sinus rhythm with ventricular parasystole
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: 30°
  Duration: 100 msec
  Voltage: Increased in I
  Morphology: Normal
ST segment: Nonspecific changes
T wave: Normal
QT interval: 410 msec
U wave:
Diagnosis: Sinus rhythm with voltage criteria for LVH in Lead I and ventricular parasystole. Note that the ventricular beats do not have a fixed coupling interval but do have a fixed interectopic interval.

ECG 19

Atrial rate: 95
Ventricular rate: 95
Rhythm: Sinus rhythm
P wave: Normal

PR interval: 120 msec
QRS complex:
Axis: 15°
Duration: 120 msec
Voltage:
Morphology:
ST segment:
T wave:
QT interval: 380 msec
U wave:
Diagnosis: Sinus rhythm with WPW

ECG 20

Atrial rate: 65
Ventricular rate: 65
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 140 msec
QRS complex:
Axis: 15°
Duration: 135 msec
Voltage:
Morphology:
ST segment:
T wave:
QT interval: 440 msec
U wave:
Diagnosis: Sinus rhythm with WPW

Day 8

The Differential Diagnosis of Wide-QRS Tachycardias

I. Basic considerations

A. Wide QRS tachycardias represent either VT or SVT with aberrant conduction.

B. VT and SVT represent vastly different clinical situations as far as etiology, extent of underlying cardiac disease, treatment, and prognosis.

C. The following discussion applies to hemodynamically stable patients; *unstable patients should have emergent electrocardioversion*.

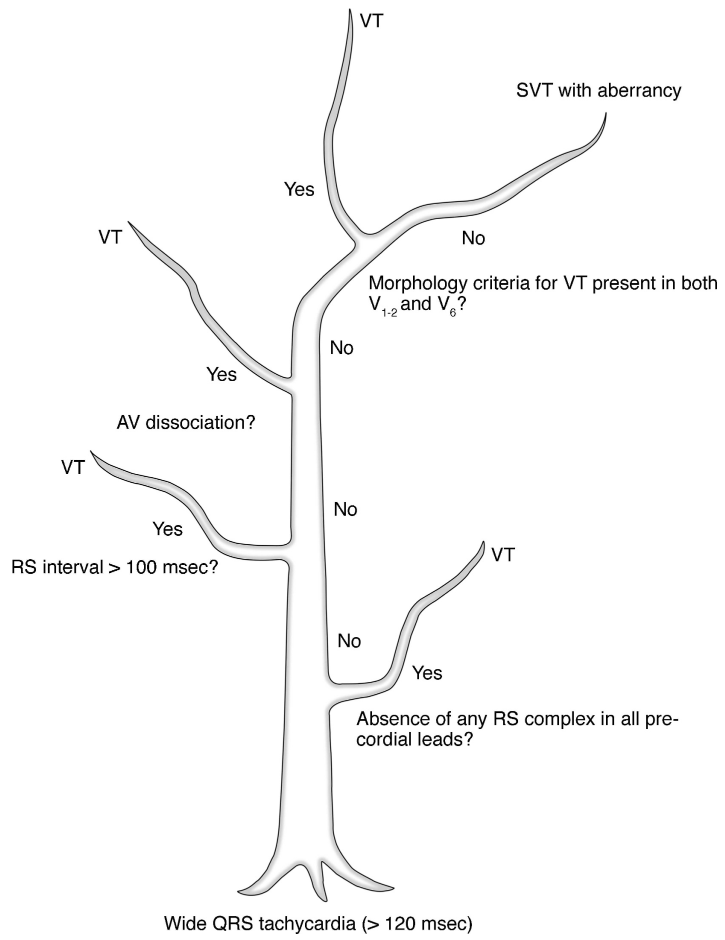
II. Brugada's criteria

A. In 1991, Brugada published a landmark paper on this problem, and his algorithm will be followed here (Brugada P, et al., A New Approach to the Differential Diagnosis of a Regular Tachycardia with a Wide QRS Complex. *Circulation*, Vol. 83, No. 5, May 1991).

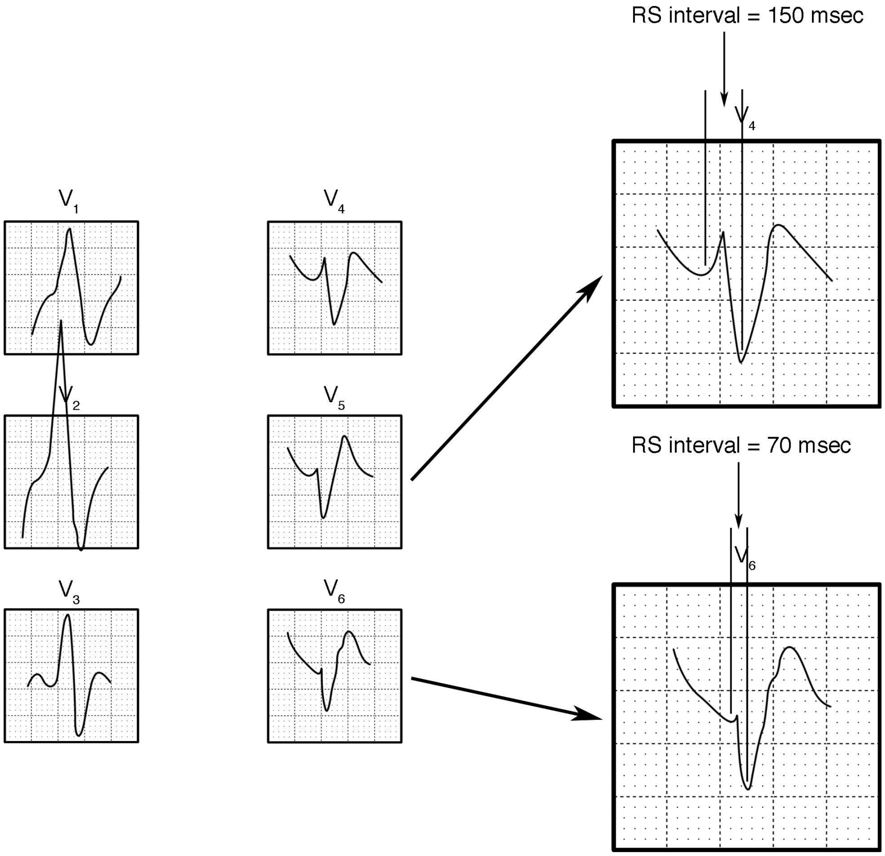
B. Brugada's criteria is based on the standard 12-lead ECG, but additional leads and techniques may aide in diagnosis.

III. Application of Brugada's criteria (see tree diagram)

A. The presence and duration of an RS complex in the precordial leads
   1. Any initial R wave followed by an S wave in the precordial leads qualifies for analysis.
   2. Lack of an RS in any precordial lead is highly specific for VT.
   3. An RS interval (defined as the interval between the onset of the R wave and the nadir of the S wave in any precordial lead) greater than 100 msec is highly specific for VT.



B. AV dissociation
   1. The presence of AV dissociation is highly specific for VT.
   2. AV dissociation can be detected on the standard ECG in about 20% of VT.
   3. Methods for detection of AV dissociation
      a. Examination of the patient may reveal *irregular cannon A waves*, in the neck veins caused by coincidental simultaneous atrial and ventricular systole.
      b. Standard ECG leads II, III, aVF, and V_2 are best for detecting P waves.
      c. Moving one of the chest leads to the V_3R position may reveal P waves.
      d. An S_5 or "Lewis' leads" is obtained by placing the right arm lead in the second right interspace and the left arm lead in the suprasternal notch with the ECG machine set to Lead I.



e. A transesophogeal or intraatrial lead may be necessary to make a definitive diagnosis
f. Another evidence of AV dissociation is the presence of occasional narrow complex beats in the midst of a wide complex tachycardia. These so-called “capture beats” result from AV nodal transmission of a fortuitously timed supraventricular beat that “captures” the ventricle.

C. The morphology of the QRS complexes in V_1–V_2 and V_6 (see table)
   1. The first determination is whether the QRS morphology in the precordial leads is a RBBB or a LBBB
   2. If the QRS complexes in V_1–V_2 and V_6 both meet criteria for VT (see diagram), VT is confirmed.
   3. If there is discordance between the criteria for VT in V_1–V_2 and V_6, SVT is strongly implicated. (Day 8-01) (Day 8-02) (Day 8-03) (Day 8-04) (Day 8-05) (Day 8-06) (Day 8-07) (Day 8-08) (Day 8-09) (Day 8-10) (Day 8-11)

Morphology Criteria VT versus SVT

Tachycardia with a RBBB-like QRS

Lead V_1

Monophasic R	VT
QR or RS	VT
Triphasic	SVT

Lead V_6

R to S ratio < 1	VT
QR or RS	VT
Monophasic R	VT
Triphasic	SVT
R to S ratio >1	SVT

Tachycardia with a LBBB-like QRS

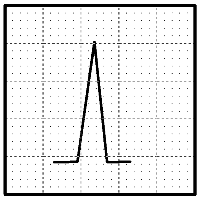
Lead V_1 or V_2

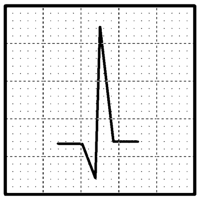
R > 30 msec	VT
> 60 msec to nadir of S	VT
Notched S	VT

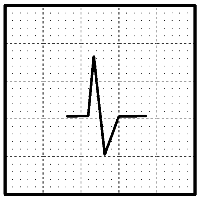
Lead V_6

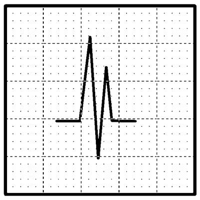
QR or QS	VT
Monophasic R	SVT

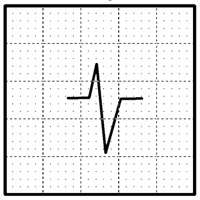
Examples of Morphology Criteria with RBBB-like QRS complexes

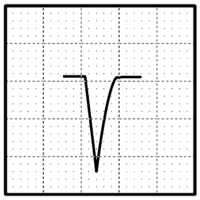
V_1

Monophasic R suggests VT

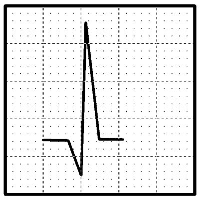
V_1

QR suggests VT

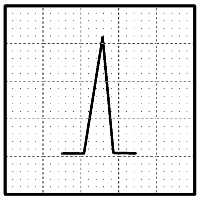
V_1

RR suggests VT

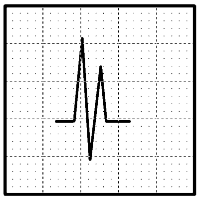
V_1

Triphasic R suggests SVT

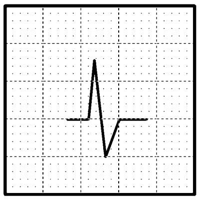
V_6

R/S ratio < 1 suggests VT

V_6

QS suggests VT

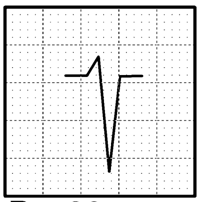
V_6

QR suggests VT

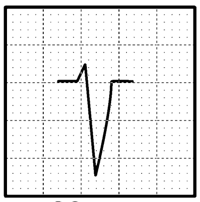
V_6

Monophasic R suggests VT

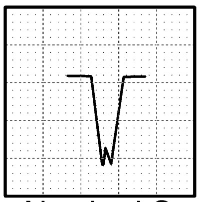
V_6

Triphasic R suggests SVT

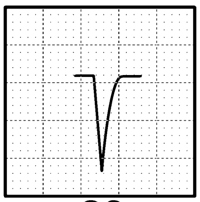
V_6

R/S ratio > 1 suggests SVT

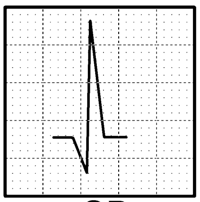
Examples of Morphology Criteria with LBBB-like QRS complexes

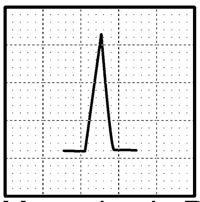
V_1

R > 30 msec suggests VT

V_1

> 60 msec to nadir of S suggests VT

V_1

Notched S suggests VT

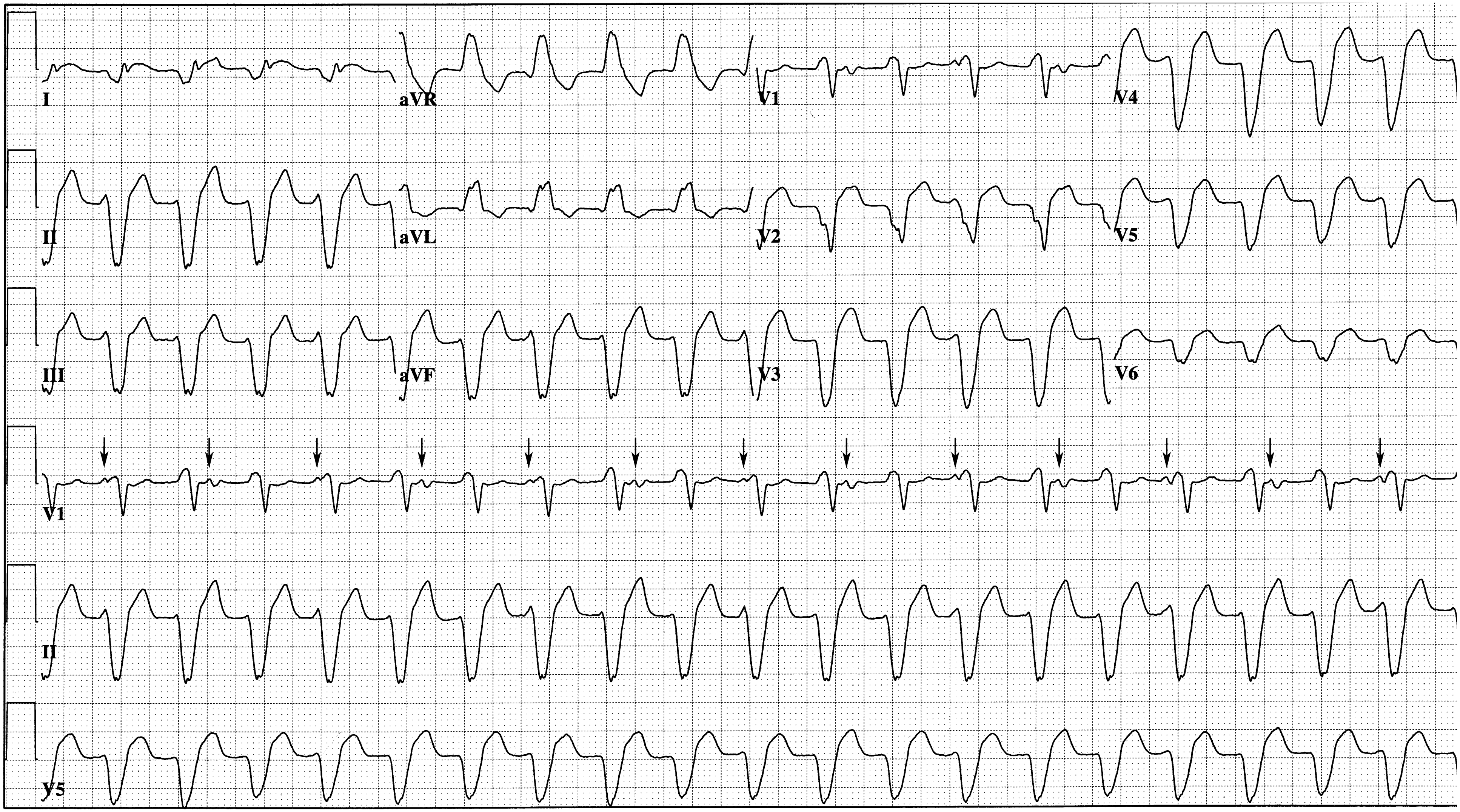
V_6

QS suggests VT

V_6

QR suggests VT

V_6

Monophasic R suggests SVT

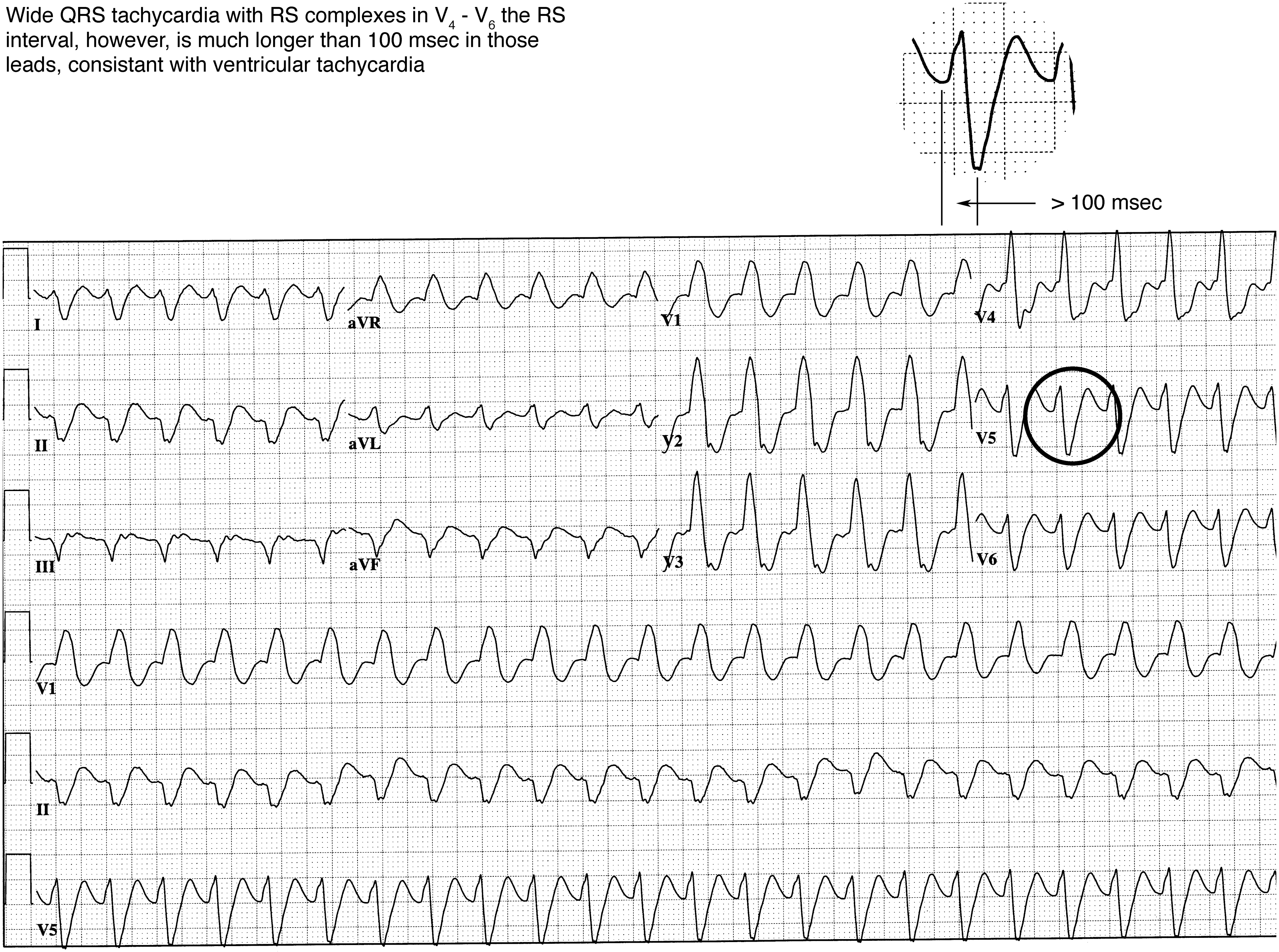
DAY 8-01

A wide QRS tachycardia with no RS complexes, consistant with ventricular tachycardia. Also present is obvious AV dissociation (arrows indicate P waves in V_1).



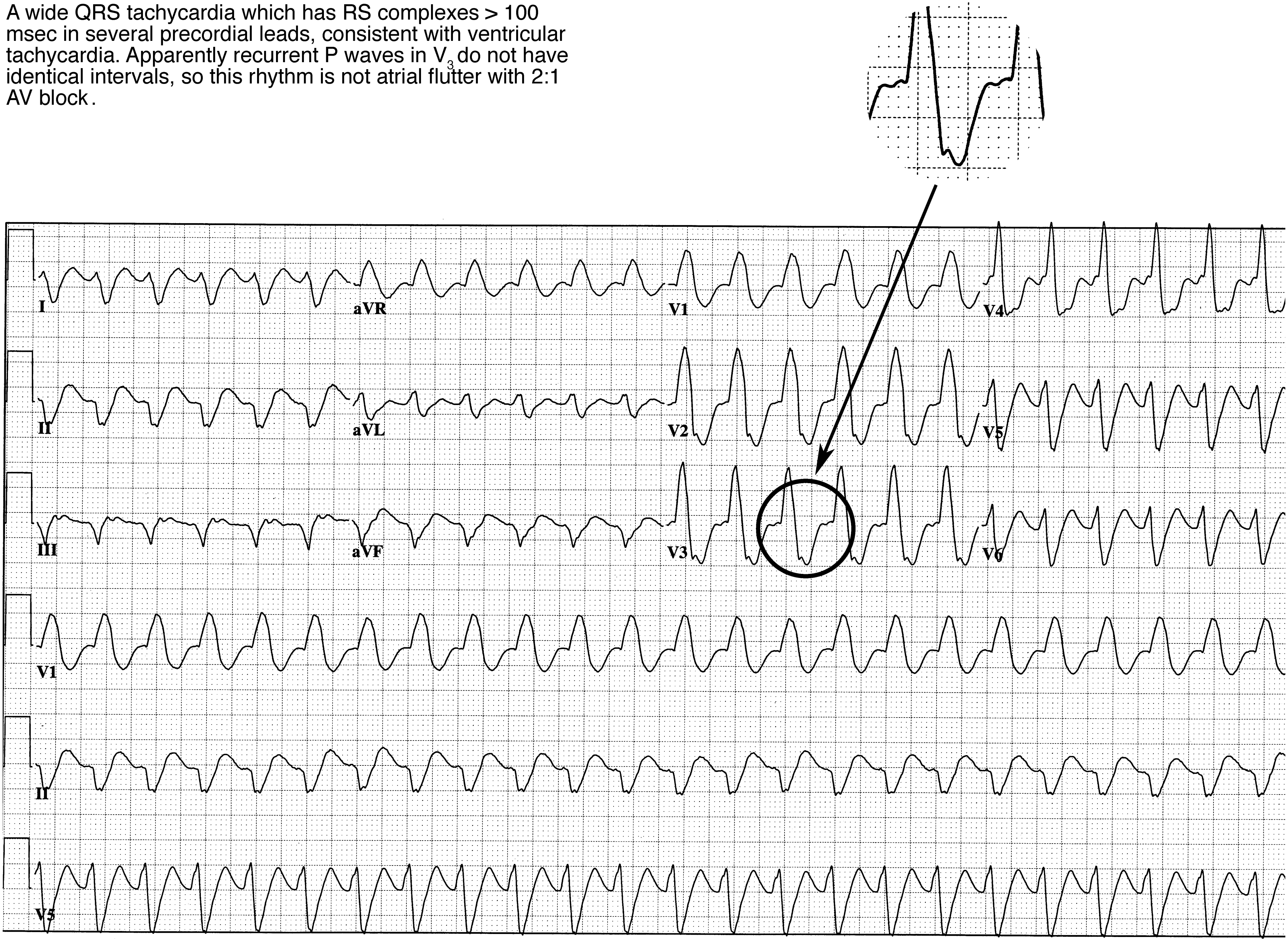
DAY 8-02

Wide QRS tachycardia with RS complexes in V_4 - V_6 the RS interval, however, is much longer than 100 msec in those leads, consistant with ventricular tachycardia



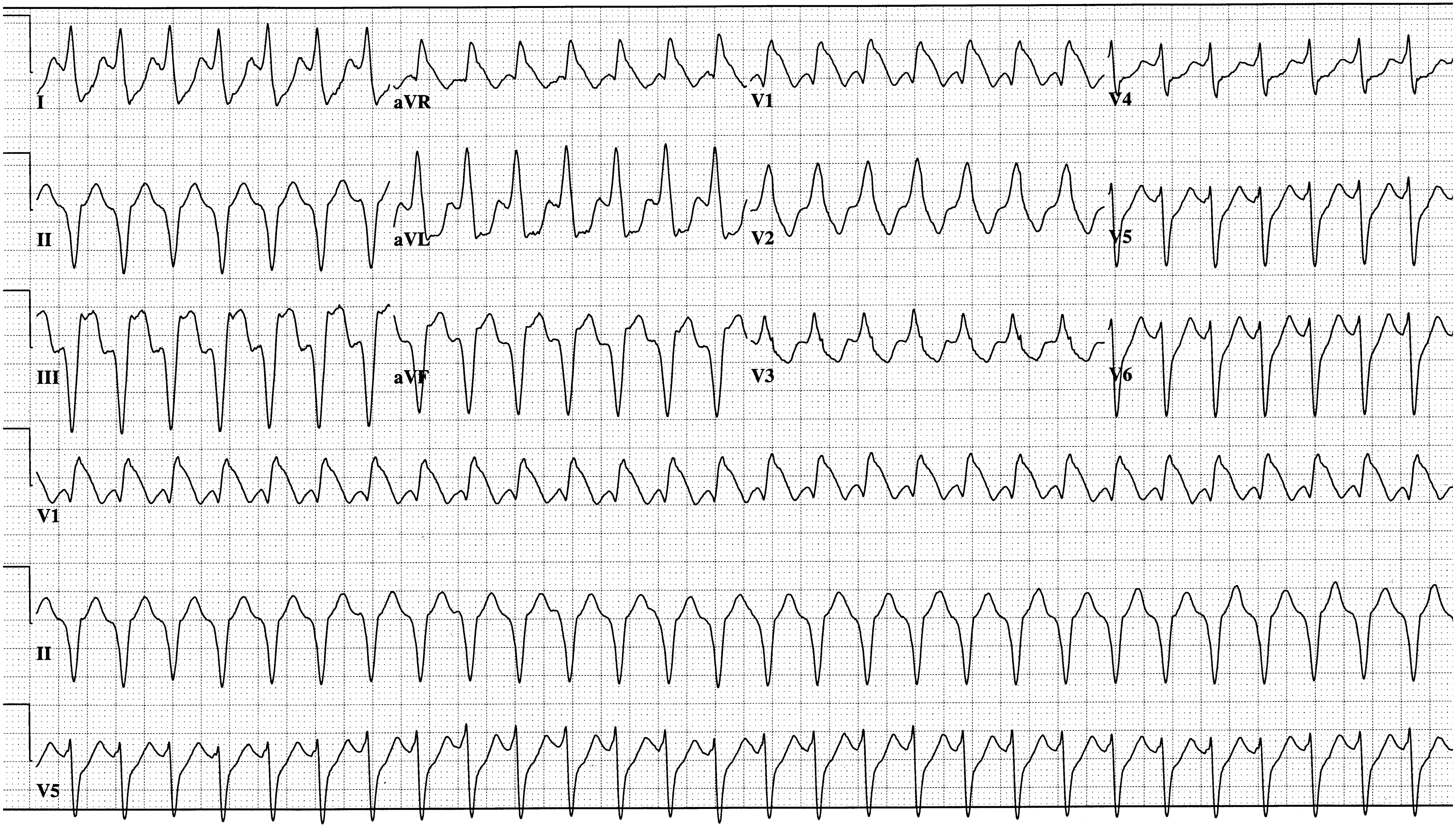
Day 8-03

A wide QRS tachycardia which has RS complexes > 100 msec in several precordial leads, consistent with ventricular tachycardia. Apparently recurrent P waves in V_3 do not have identical intervals, so this rhythm is not atrial flutter with 2:1 AV block.



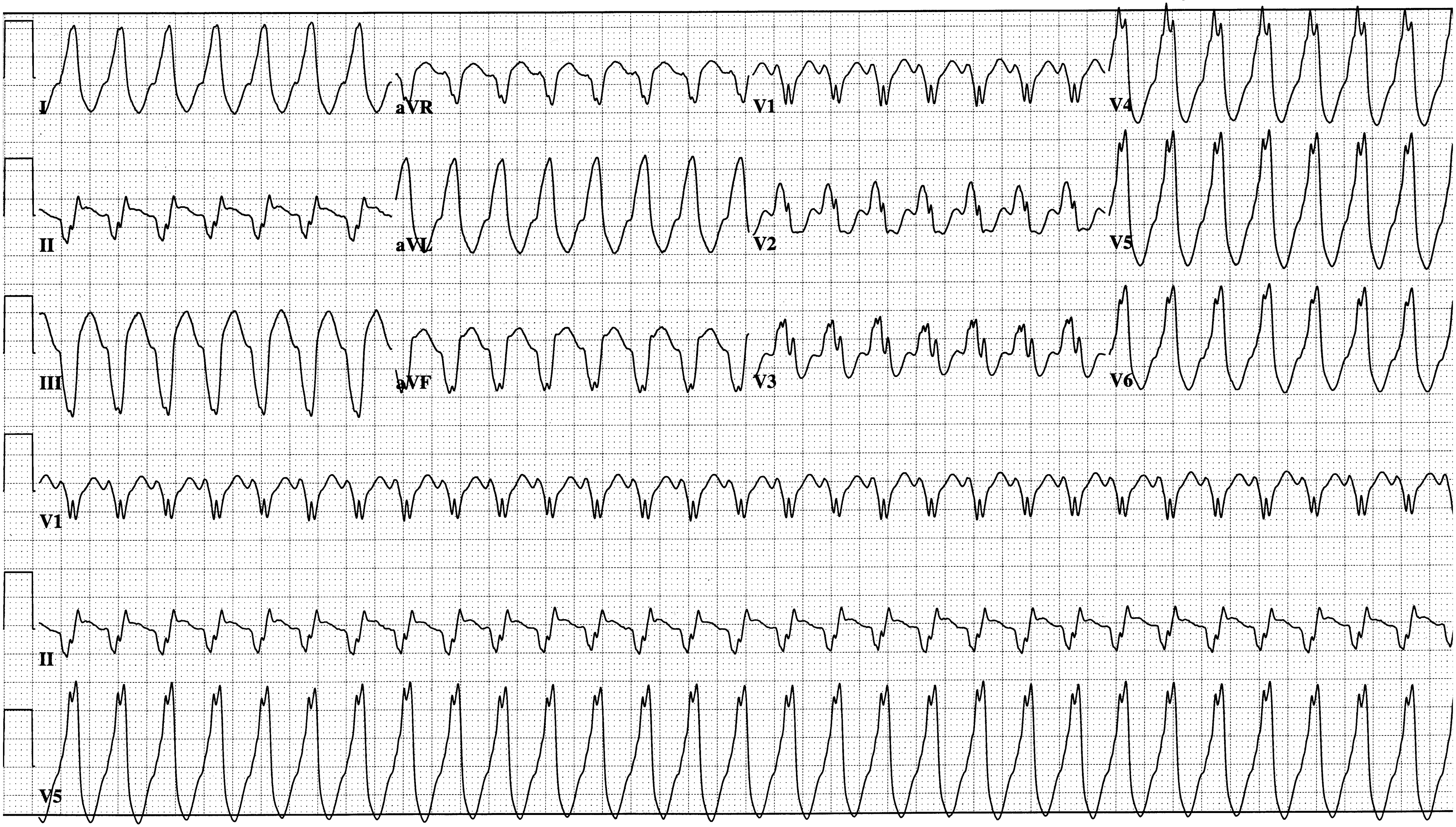
DAY 8-04

A wide QRS tachycardia with RS complexes in V_4 - V_6. The RS intervals in these leads it < 100 msec. There is no obvious AV dissociation. This is a RBBB-like morphology with an RSR' in V_1 and an R/S < 1 in V_6. This combination suggests a supraventricular tachycardia with aberrancy.



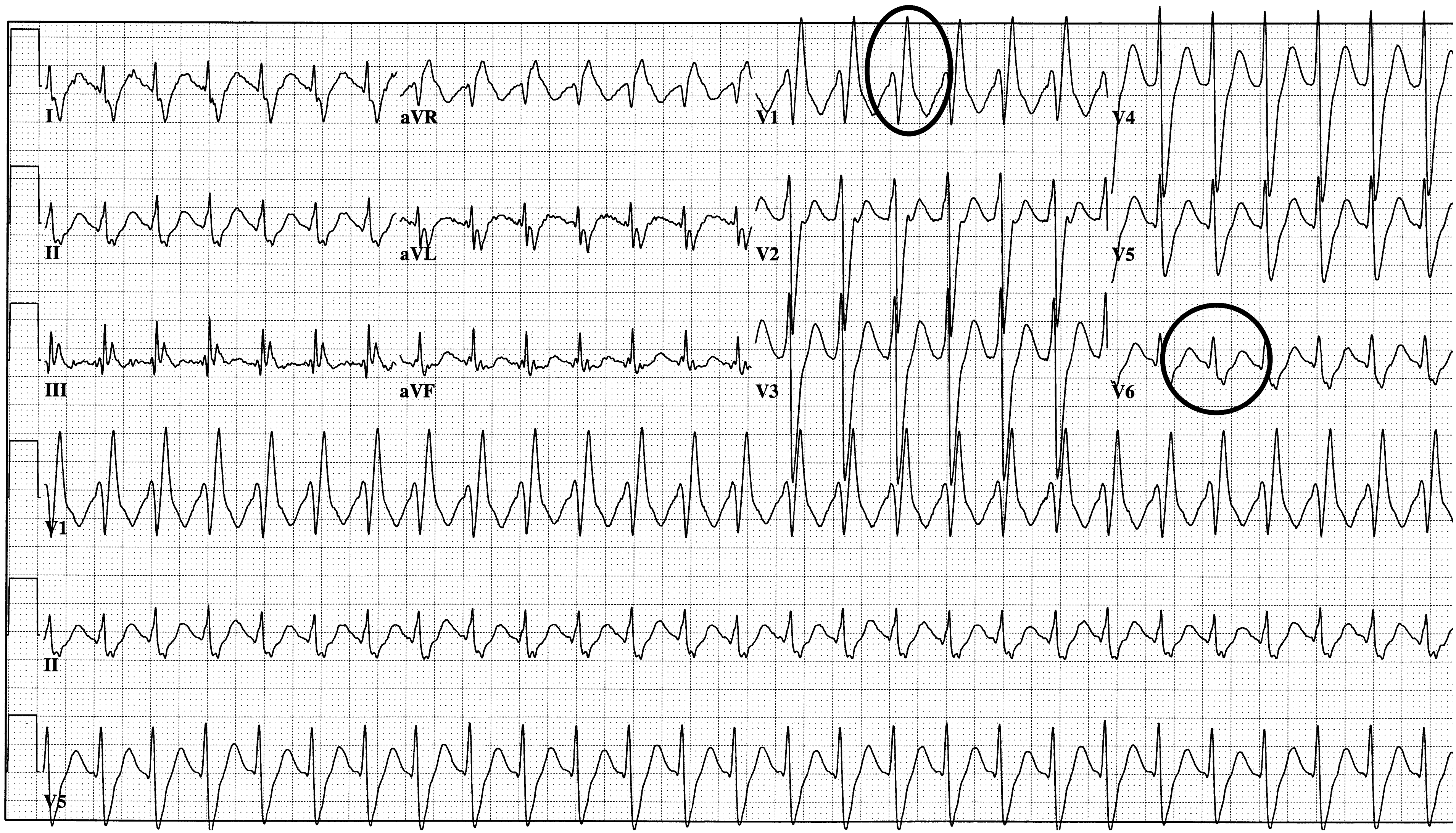
DAY 8-05

A wide QRS tachycardia without obvious RS complexes consistent with ventricular tachycardia



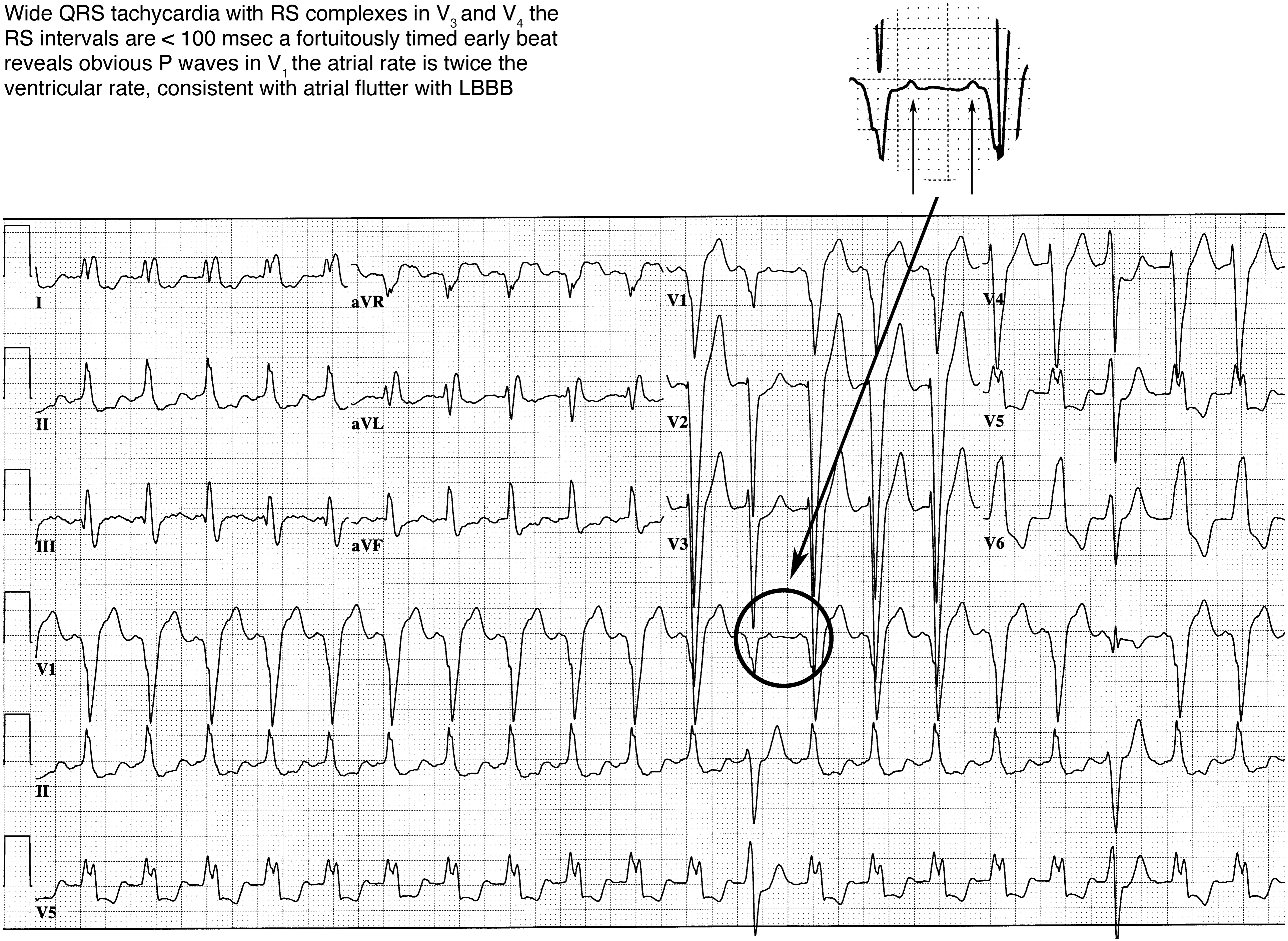
DAY 8-06

Wide QRS tachycardia with RS complexes in V_2 - V_6 all of the RS intervals are < 100 msec there is no evidence of AV dissociation. This is a RBBB-like morphology with an RSR' in V_1 and an R/S > 1 in V_6. This combination is consistent with a supraventricular tachycardia with aberrancy.



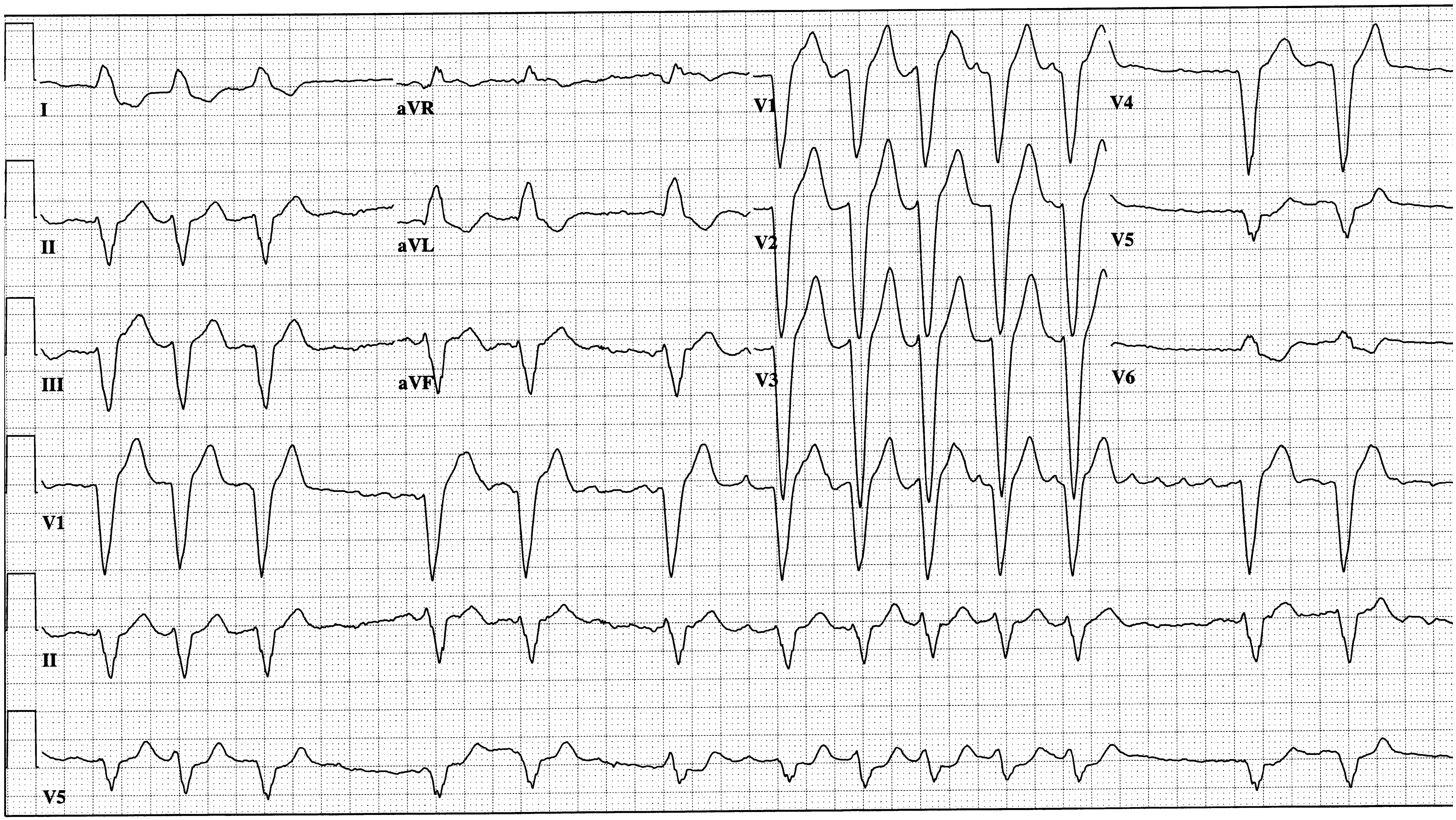
DAY 8-07

Wide QRS tachycardia with RS complexes in V_3 and V_4 the RS intervals are < 100 msec a fortuitously timed early beat reveals obvious P waves in V_1 the atrial rate is twice the ventricular rate, consistent with atrial flutter with LBBB



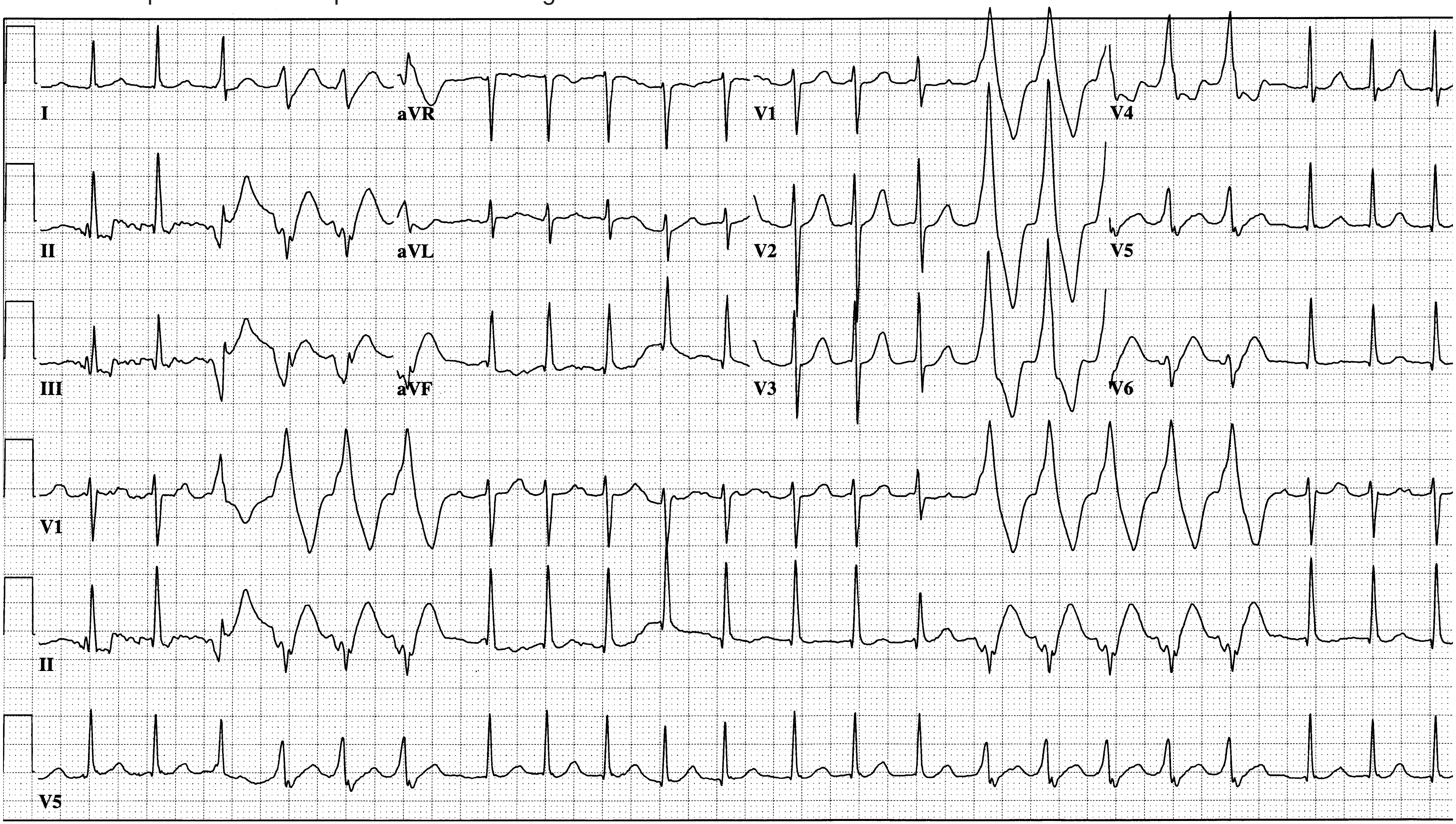
DAY 8-08

A wide QRS tachycardia with irregularly irregular QRS complexes and an undulating baseline consistent with atrial fibrilation with LBBB. Using Brugada's criteria, there is an RS complex in V_3 which is < 100 msec. There is no evidence of AV dissociation. The morphology criteria favor a supraventricular tachycardia with aberrancy.



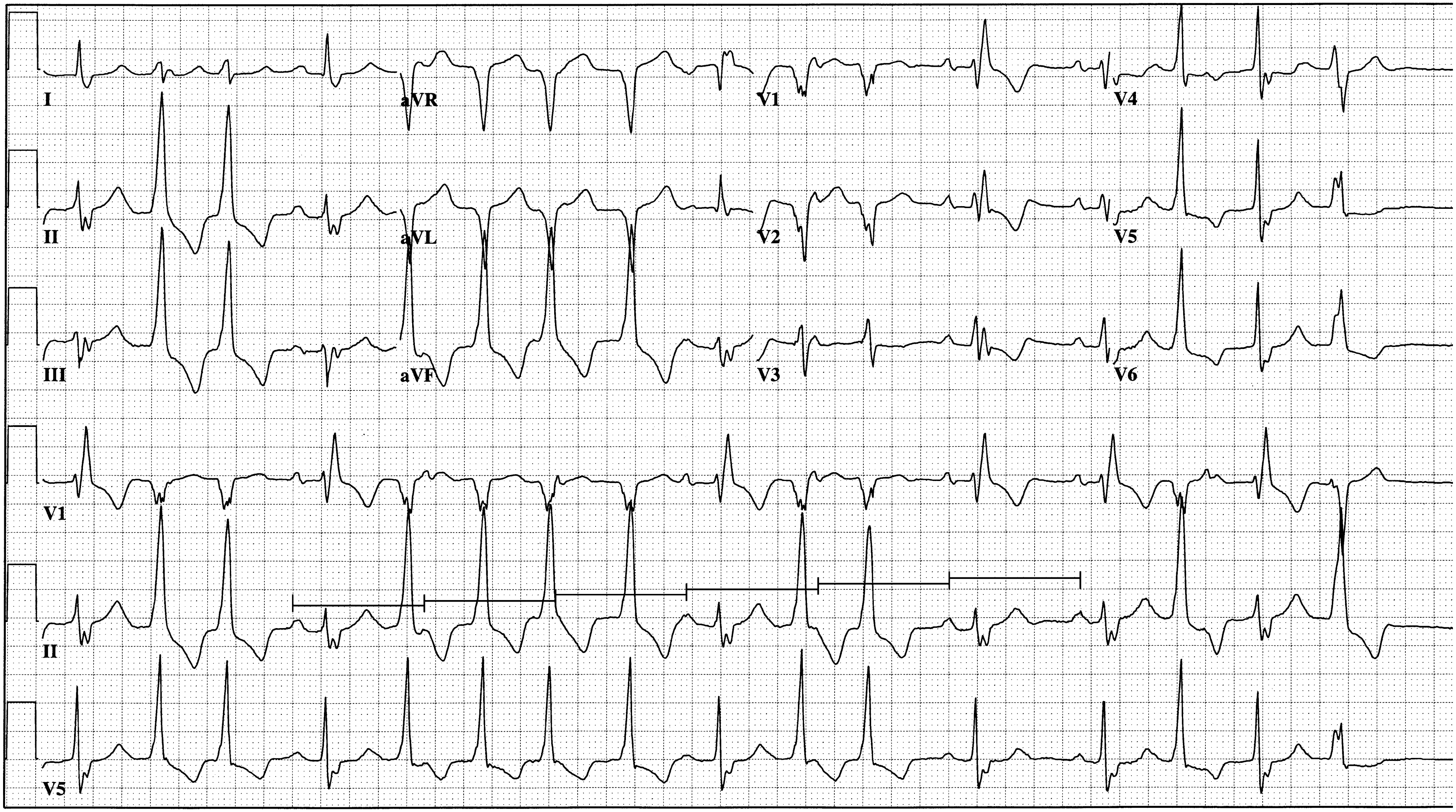
DAY 8-09

A narrow complex tachycardia with periods of wide complex tachycardia. There are subtle variations in the RR intervals and no obvious P waves, consistent with atrial fibrillation. The wide complex portions are at essentially the same rate, and the first episode begins with a beat which has a morphology between that of the preceding and succeeding beats. All of this suggests that the wide complex beats are supraventricular in origin.



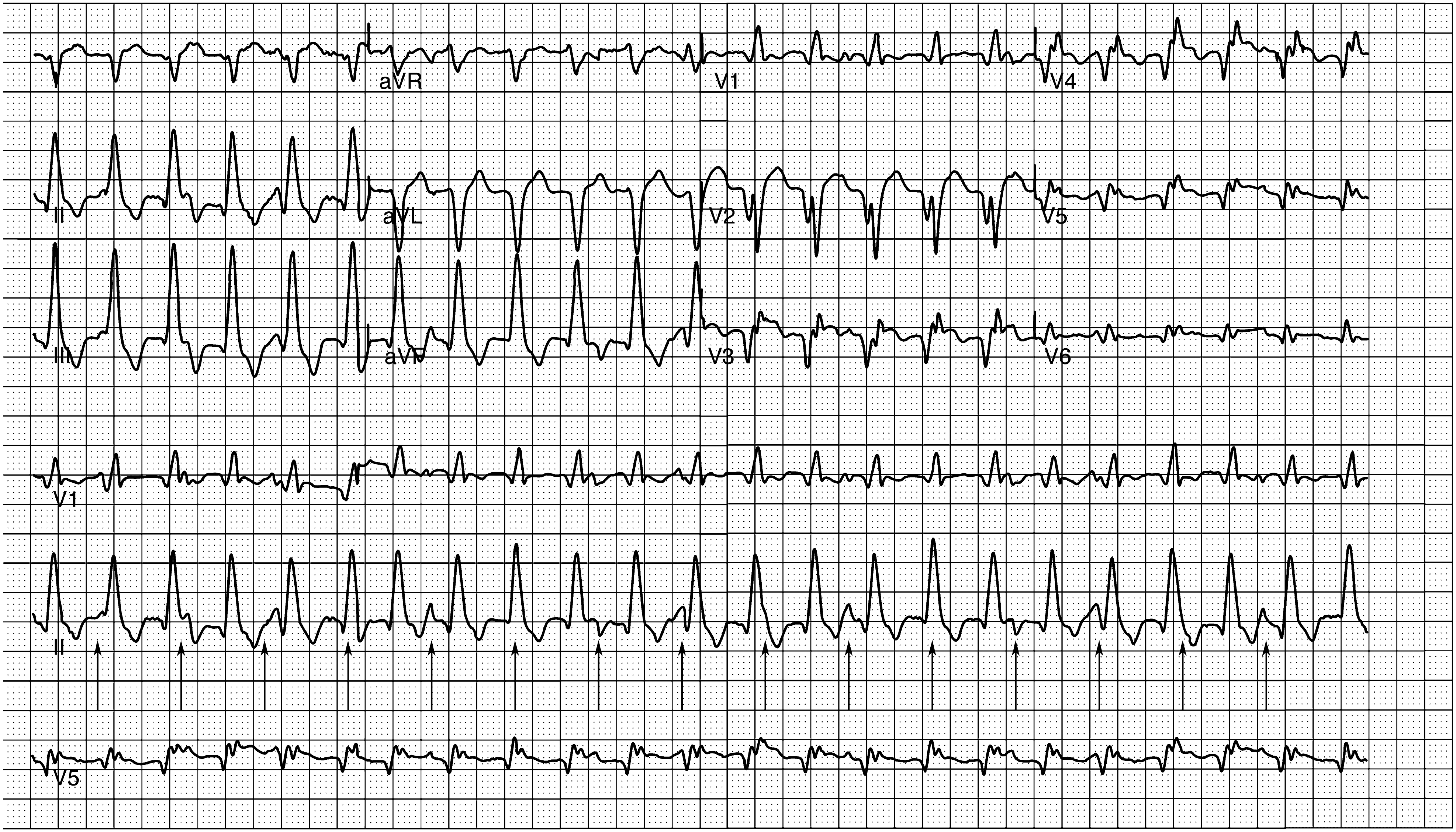
DAY 8-10

Sinus rhythm with bursts of wide complex tachycardia. The horizontal lines indicate the interval between P waves and demonstrate AV dissocation. The wide complex rhythm is therefore wide complex tachycardia.



DAY 8-11

A wide complex tachycardia which lacks RS complexes in the precordial leads, consistent with ventricular tachycardia. In addition, AV dissociation can easily be observed in Lead II (arrows indicate P waves).



Sample Tracings

ECG 1

Atrial rate: ____________

Ventricular rate: ____________

Rhythm: ____________

P wave: ____________

PR interval: ____________

QRS complex:

Axis: ____________

Duration: ____________

Voltage: ____________

Morphology: ____________

ST segment: ____________

T wave: ____________

QT interval: ____________

U wave: ____________

Diagnosis: ____________

____

ECG 2

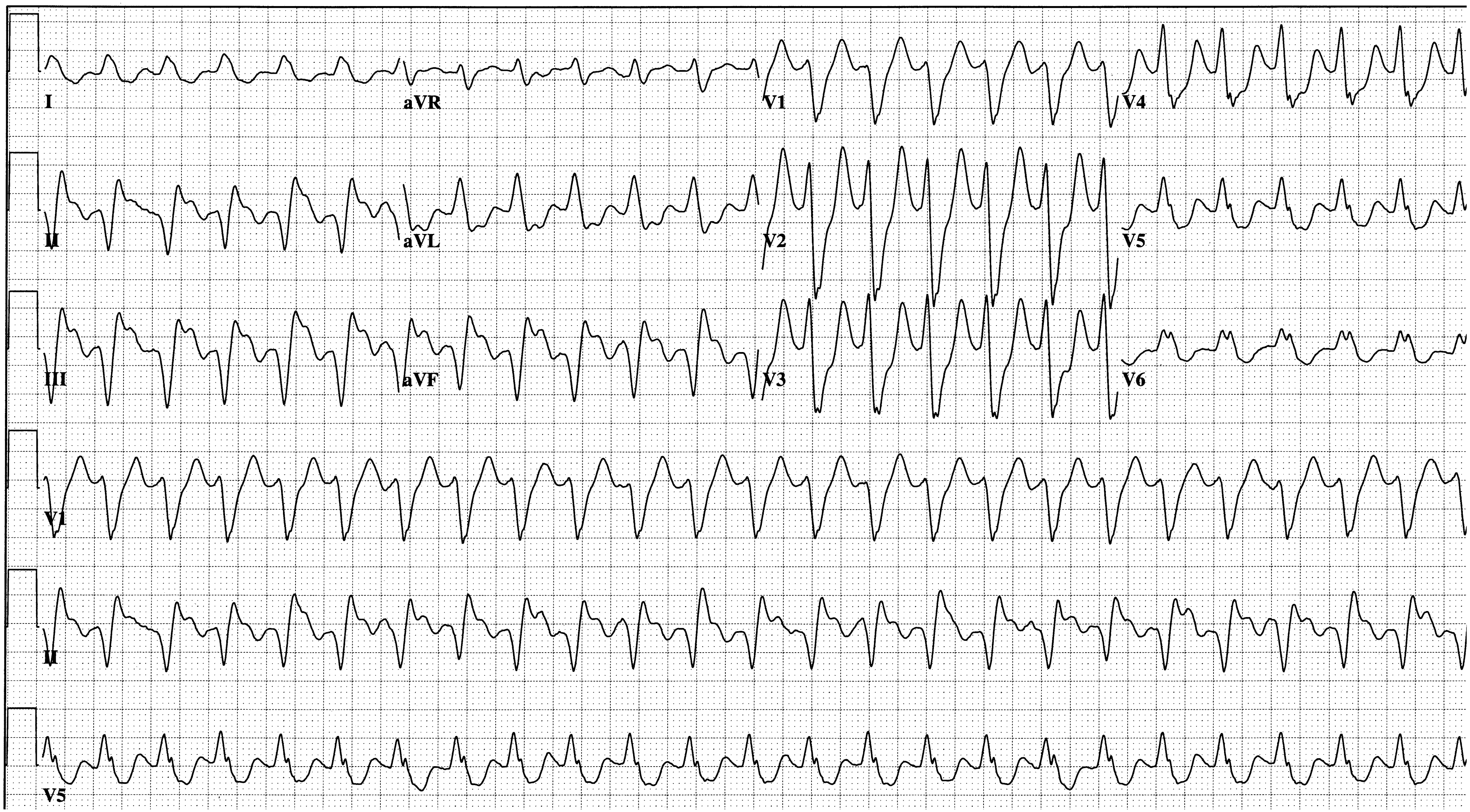
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG 3

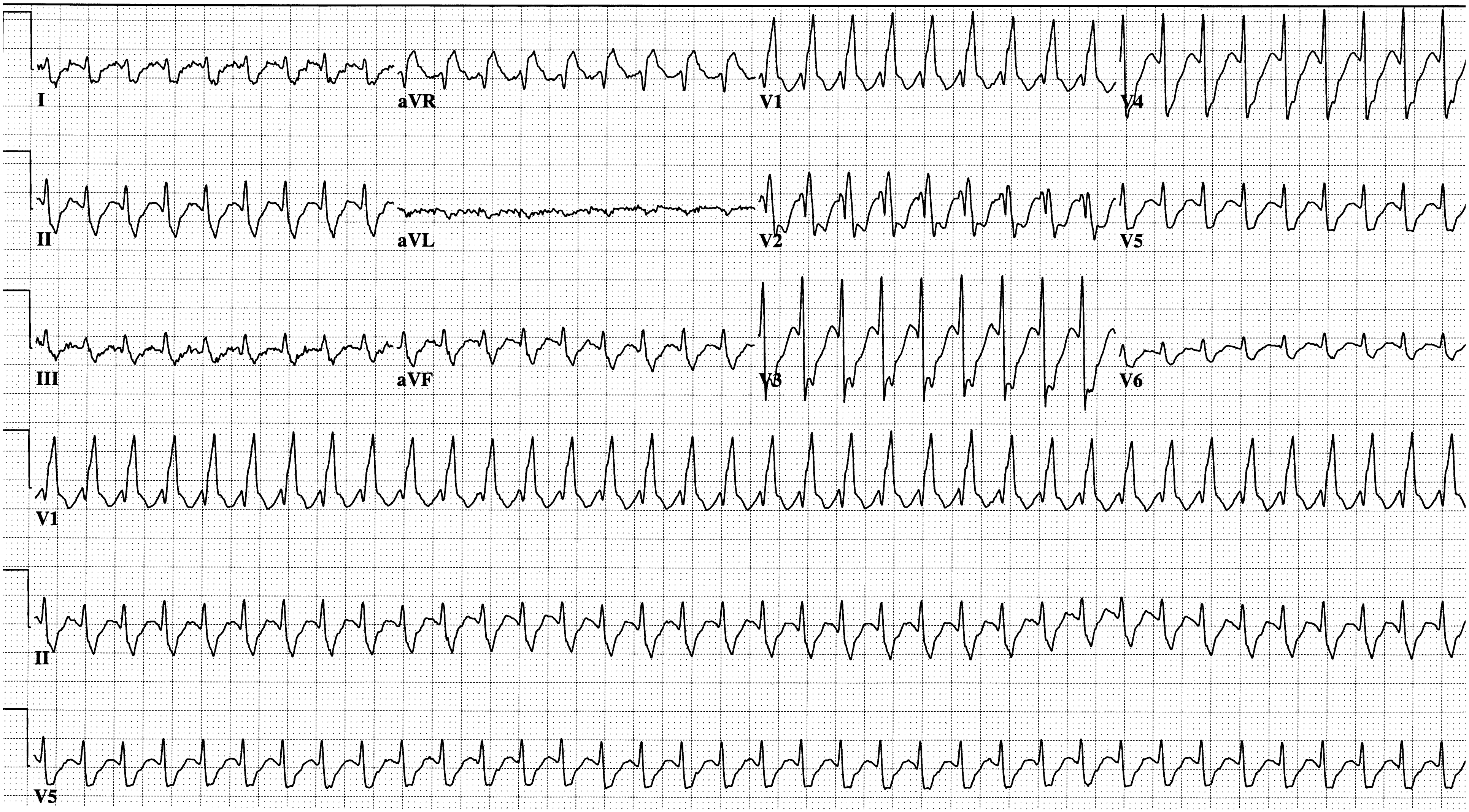
Atrial rate: ____________________ QRS complex: ST segment: ____________________

Ventricular rate: ____________________ Axis: ____________________ T wave: ____________________

Rhythm: ____________________ Duration: ____________________ QT interval: ____________________

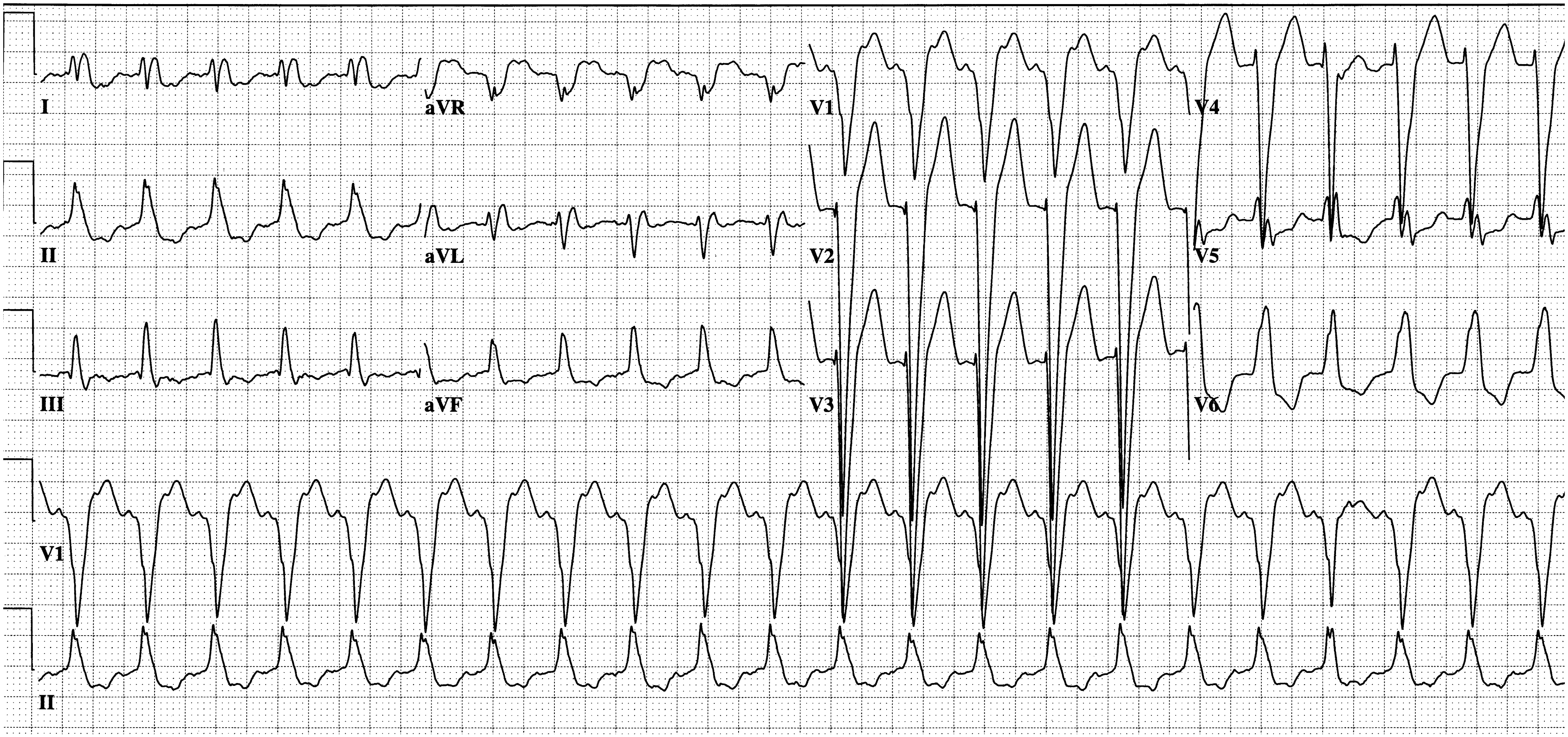
P wave: ____________________ Voltage: ____________________ U wave: ____________________

PR interval: ____________________ Morphology: ____________________ Diagnosis: ____________________



ECG 4

Atrial rate: ________	QRS complex:	ST segment: ________
Ventricular rate: ________	Axis: ________	T wave: ________
Rhythm: ________	Duration: ________	QT interval: ________
P wave: ________	Voltage: ________	U wave: ________
PR interval: ________	Morphology: ________	Diagnosis: ________



ECG 5

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

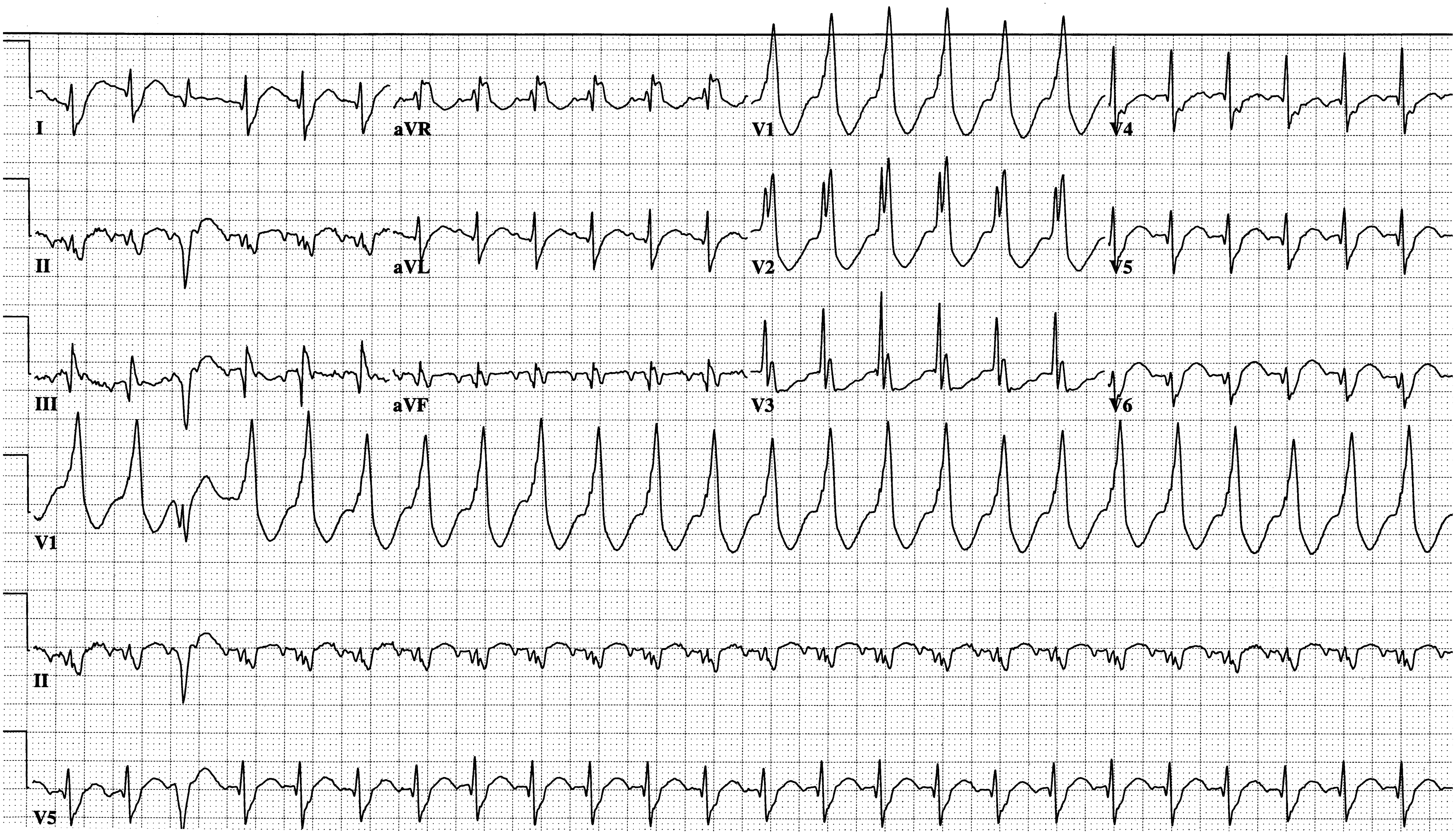
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG 6

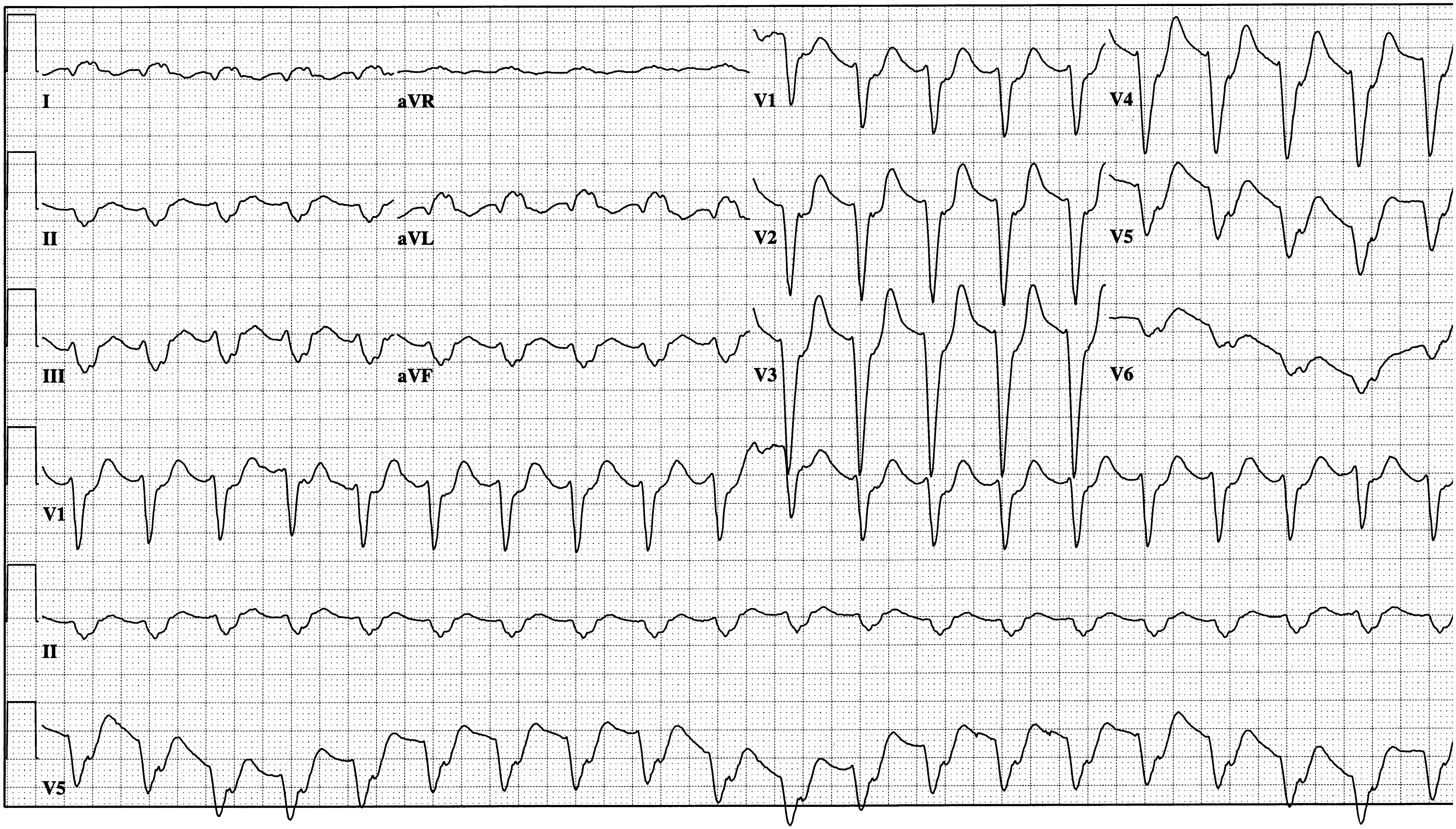
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______

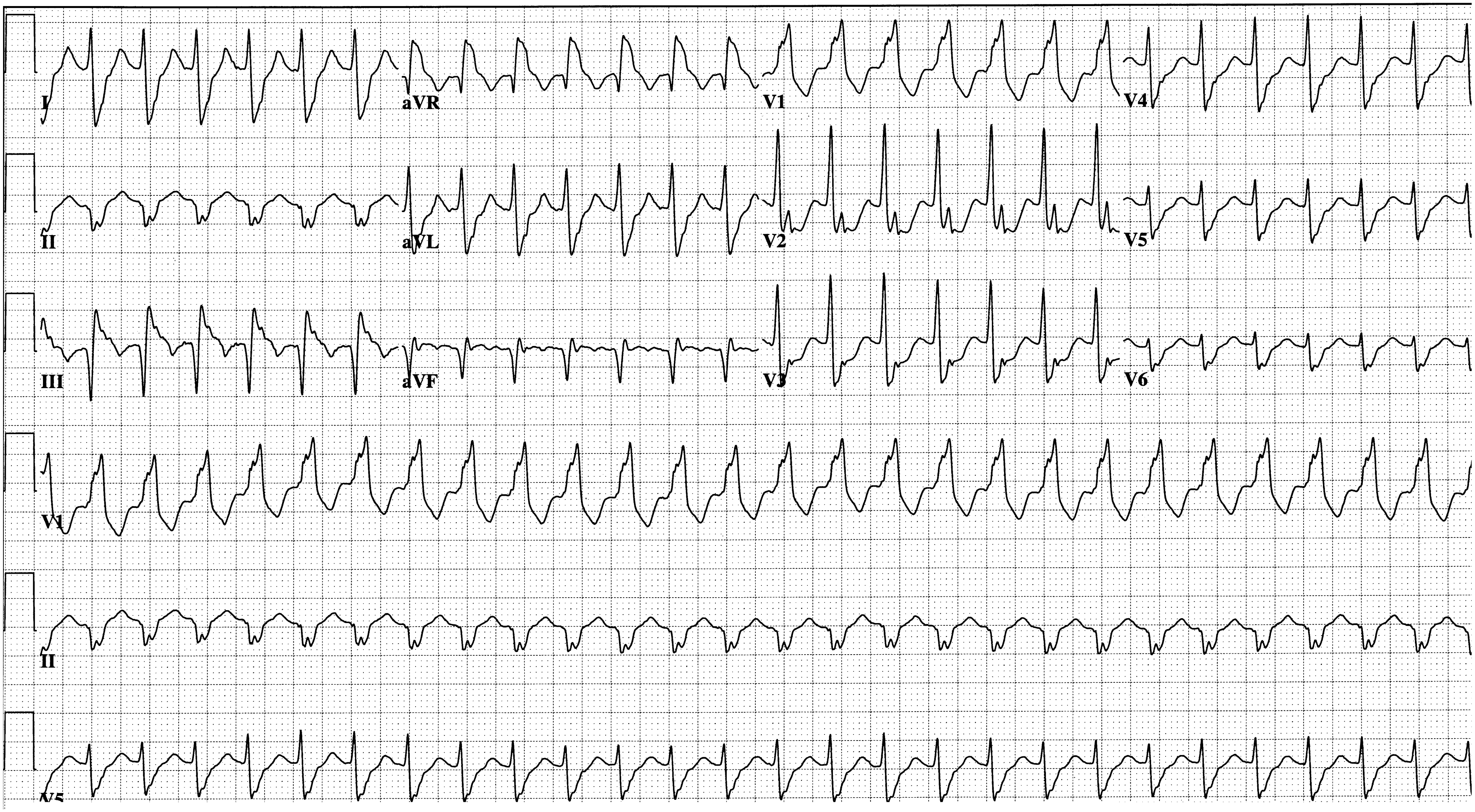


ECG 7

Atrial rate: ______________________
Ventricular rate: ______________________
Rhythm: ______________________
P wave: ______________________
PR interval: ______________________

QRS complex:
Axis: ______________________
Duration: ______________________
Voltage: ______________________
Morphology: ______________________

ST segment: ______________________
T wave: ______________________
QT interval: ______________________
U wave: ______________________
Diagnosis: ______________________
____



ECG 8

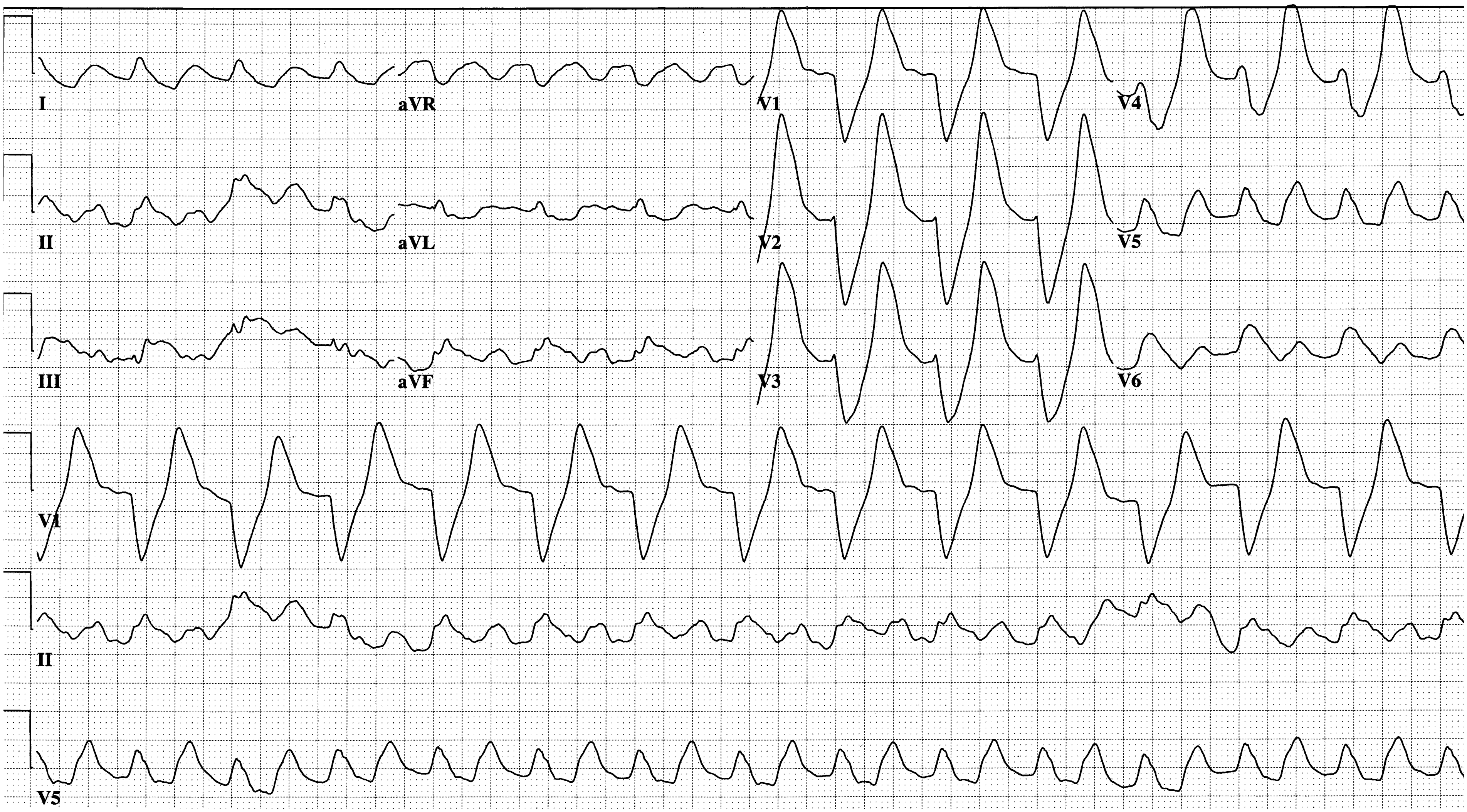
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG 9

Atrial rate: ____________________ QRS complex: ST segment: ____________________

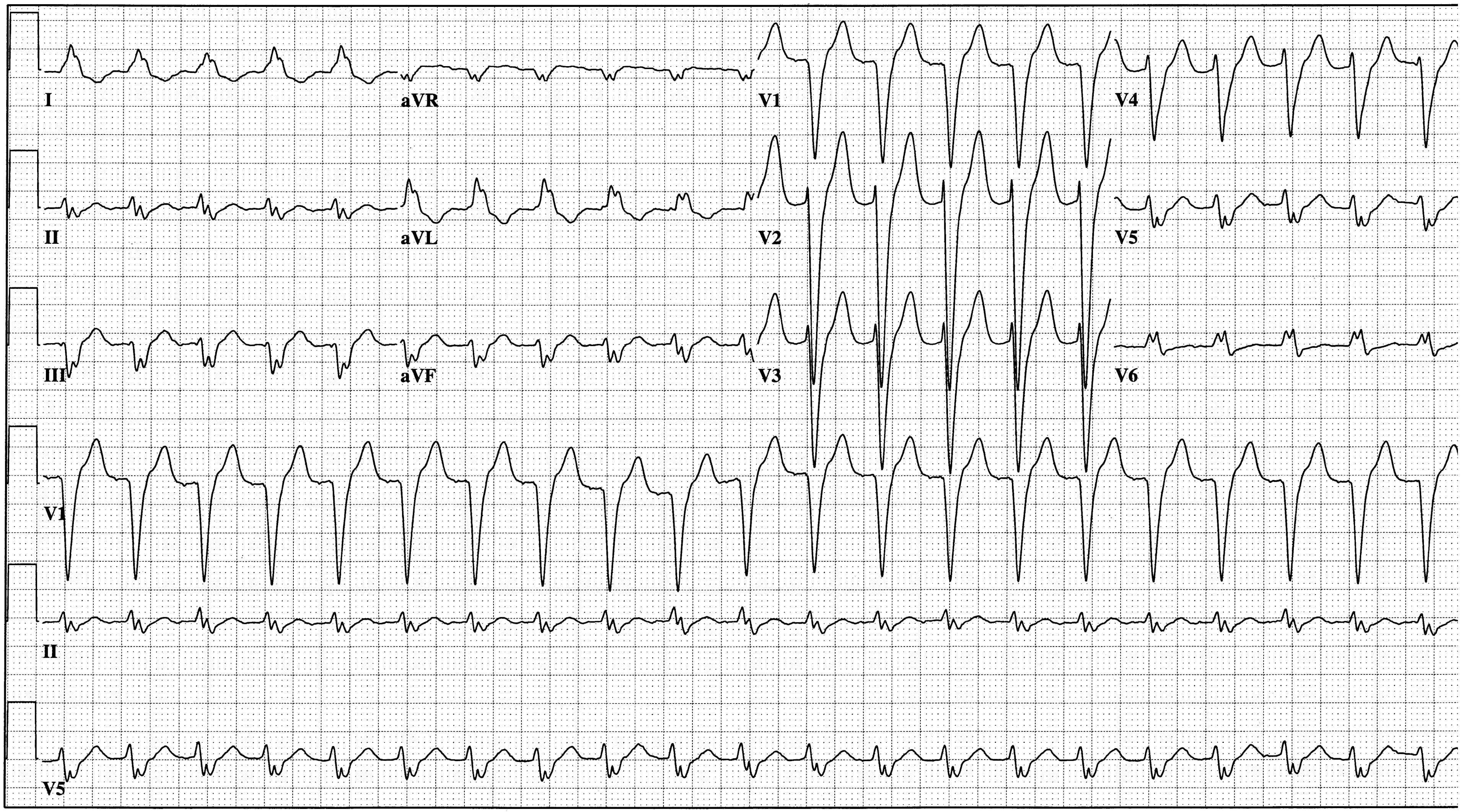
Ventricular rate: ____________________ Axis: ____________________ T wave: ____________________

Rhythm: ____________________ Duration: ____________________ QT interval: ____________________

P wave: ____________________ Voltage: ____________________ U wave: ____________________

PR interval: ____________________ Morphology: ____________________ Diagnosis: ____________________

____



ECG 10

Atrial rate: __________

Ventricular rate: __________

Rhythm: __________

P wave: __________

PR interval: __________

QRS complex:

Axis: __________

Duration: __________

Voltage: __________

Morphology: __________

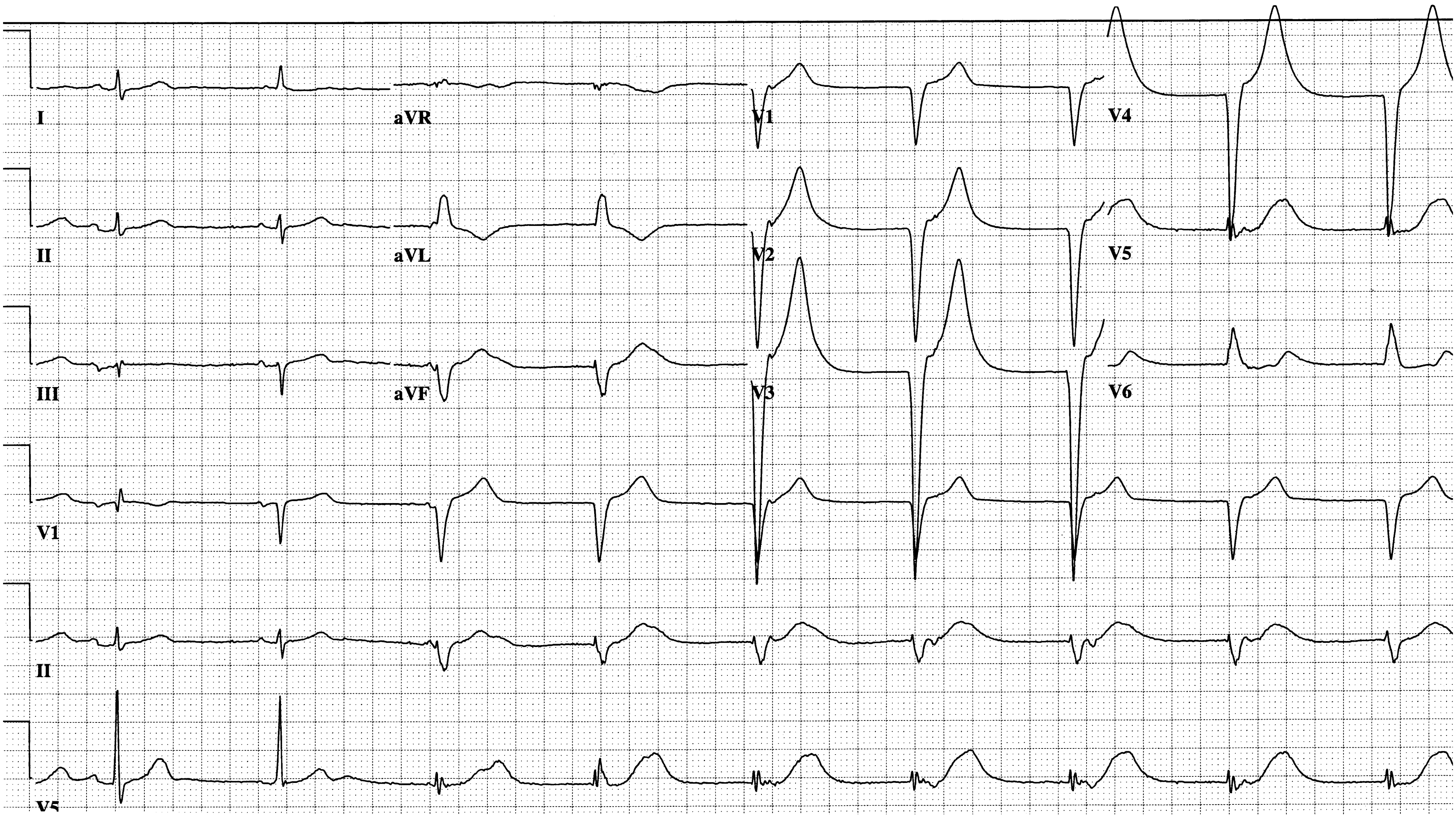
ST segment: __________

T wave: __________

QT interval: __________

U wave: __________

Diagnosis: __________



ECG 11

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

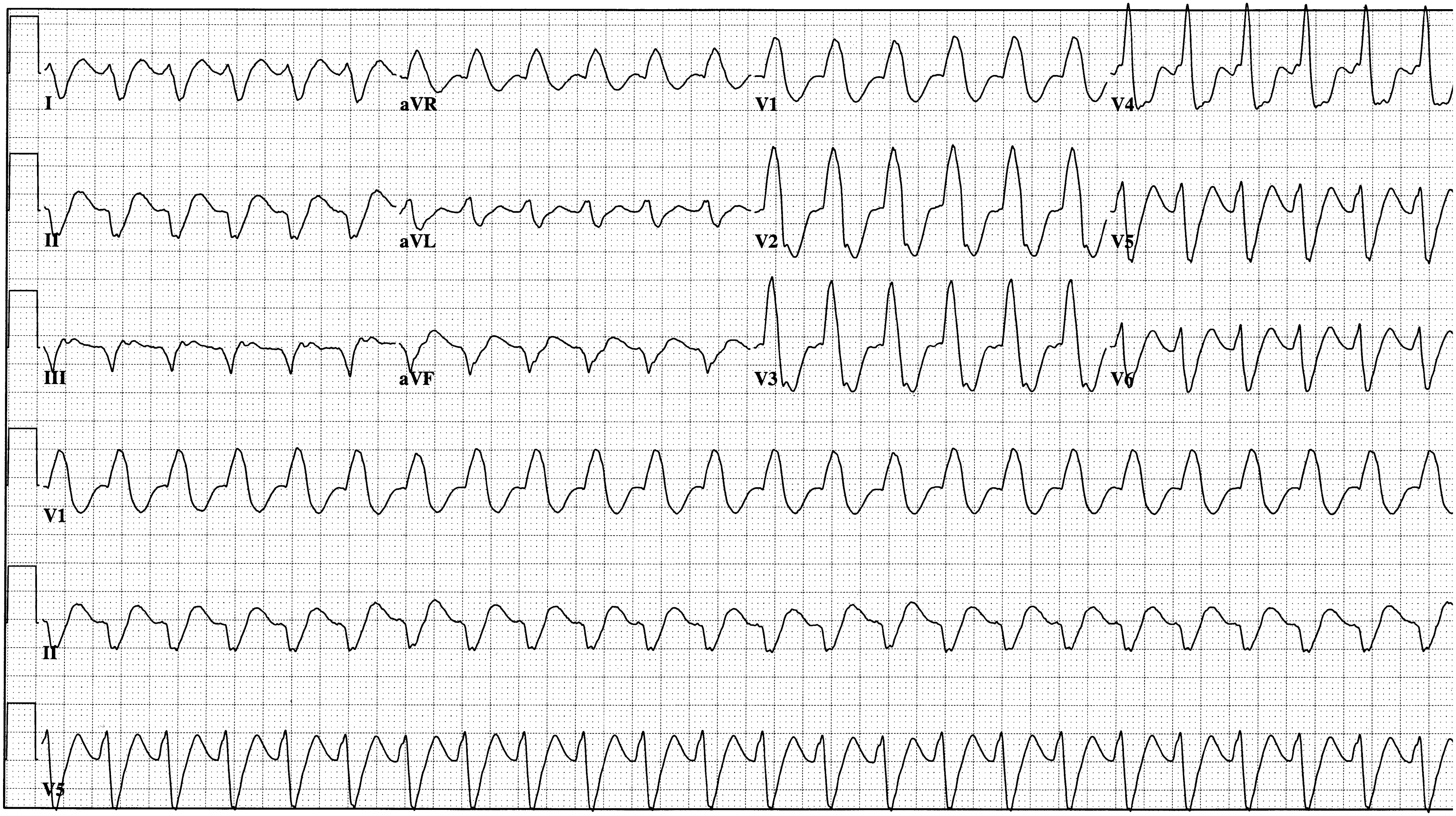
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 12

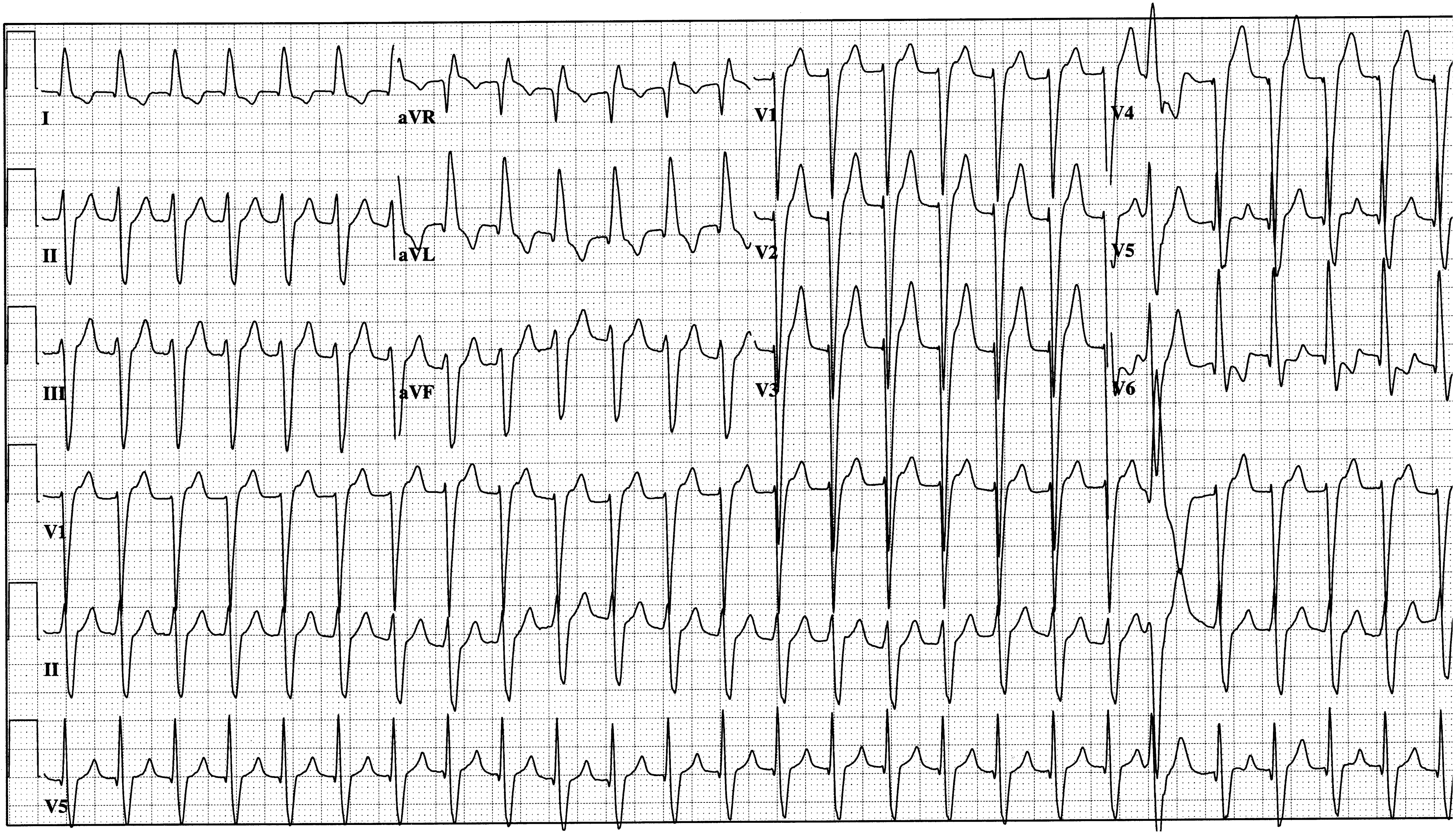
Atrial rate: ________ QRS complex: ST segment: ________

Ventricular rate: ________ Axis: ________ T wave: ________

Rhythm: ________ Duration: ________ QT interval: ________

P wave: ________ Voltage: ________ U wave: ________

PR interval: ________ Morphology: ________ Diagnosis: ________



ECG 13

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

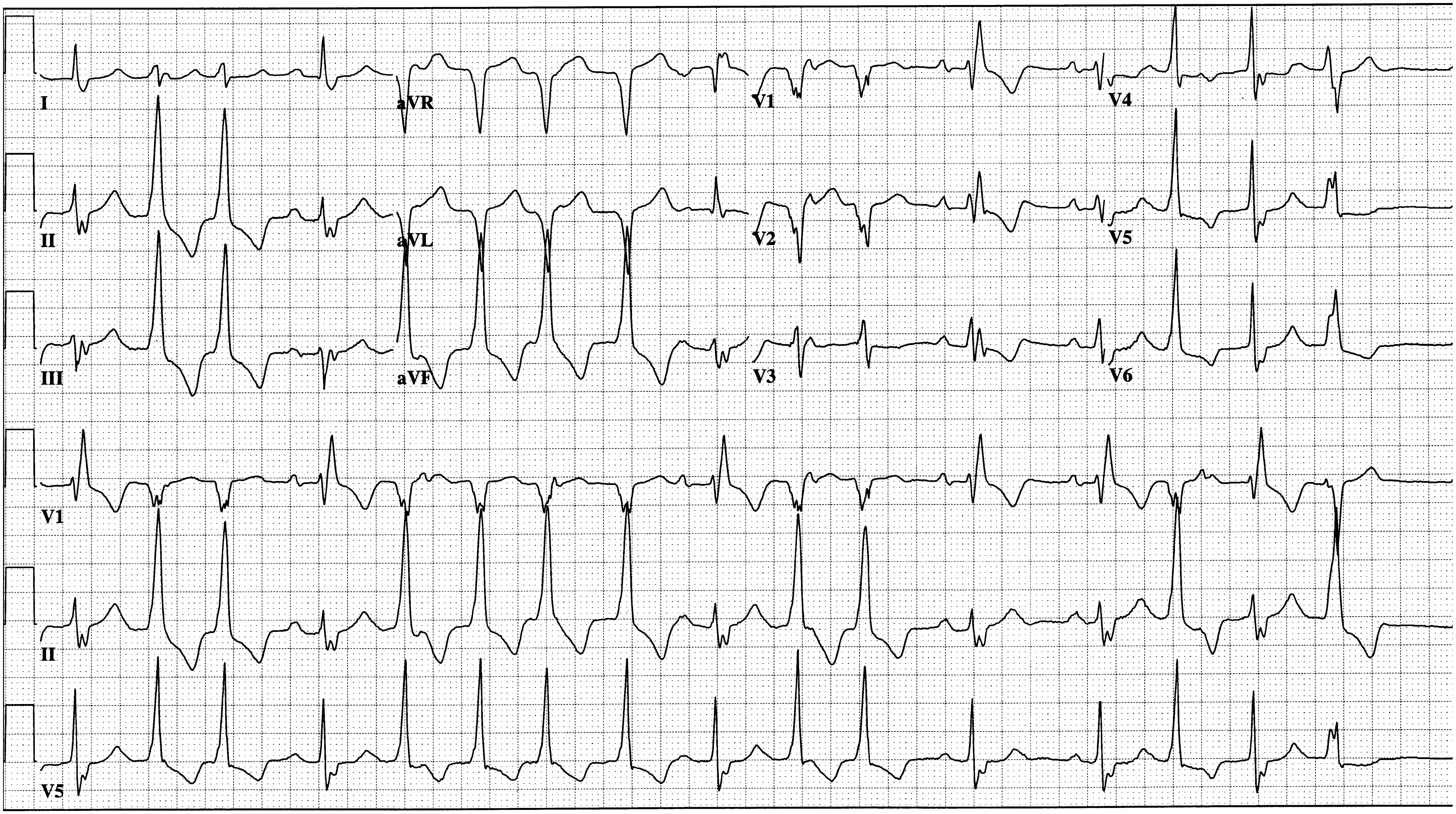
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 14

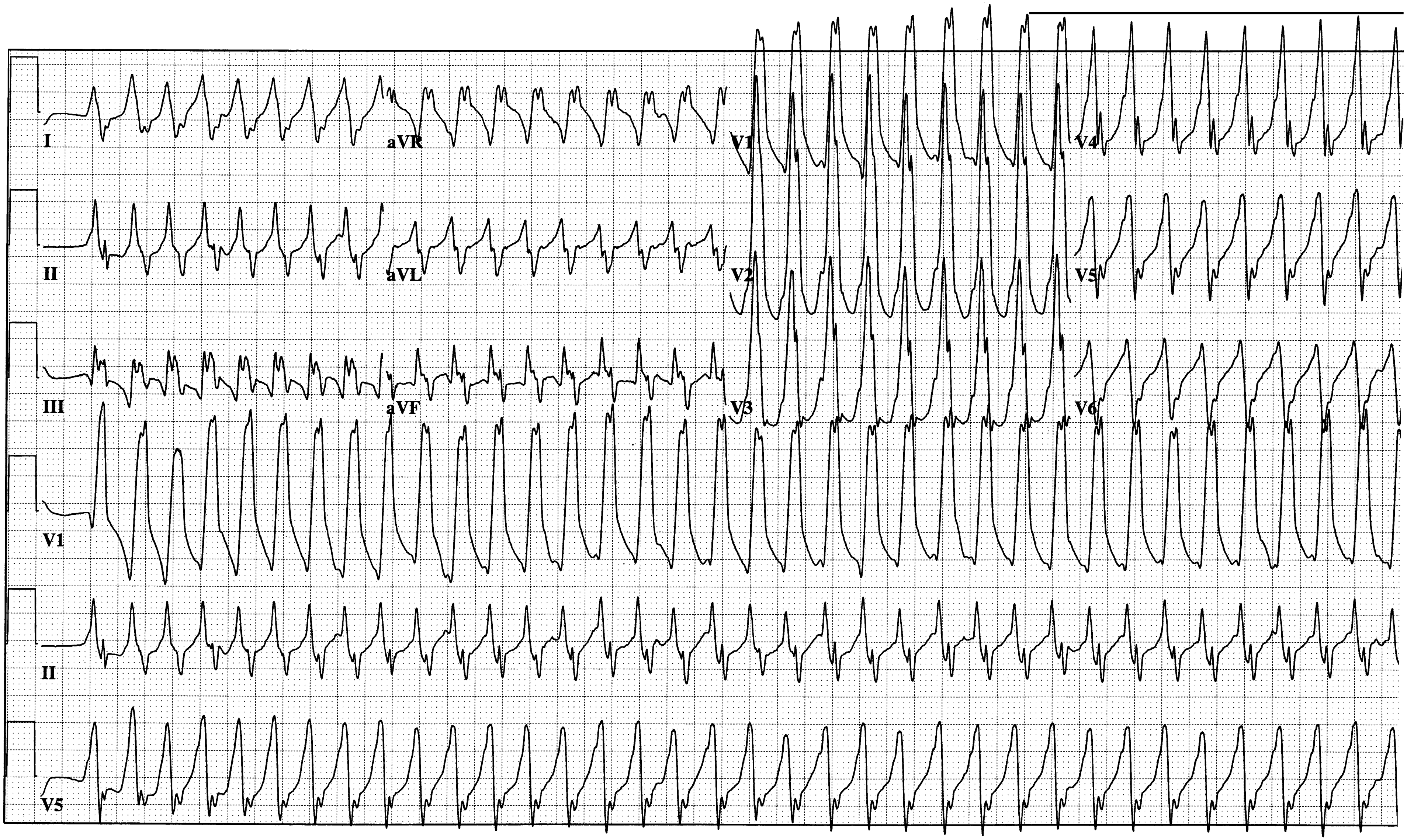
Atrial rate: ____________ QRS complex: ST segment: ____________

Ventricular rate: ____________ Axis: ____________ T wave: ____________

Rhythm: ____________ Duration: ____________ QT interval: ____________

P wave: ____________ Voltage: ____________ U wave: ____________

PR interval: ____________ Morphology: ____________ Diagnosis: ____________



ECG 15

Atrial rate: ______________

Ventricular rate: ______________

Rhythm: ______________

P wave: ______________

PR interval: ______________

QRS complex:

Axis: ______________

Duration: ______________

Voltage: ______________

Morphology: ______________

ST segment: ______________

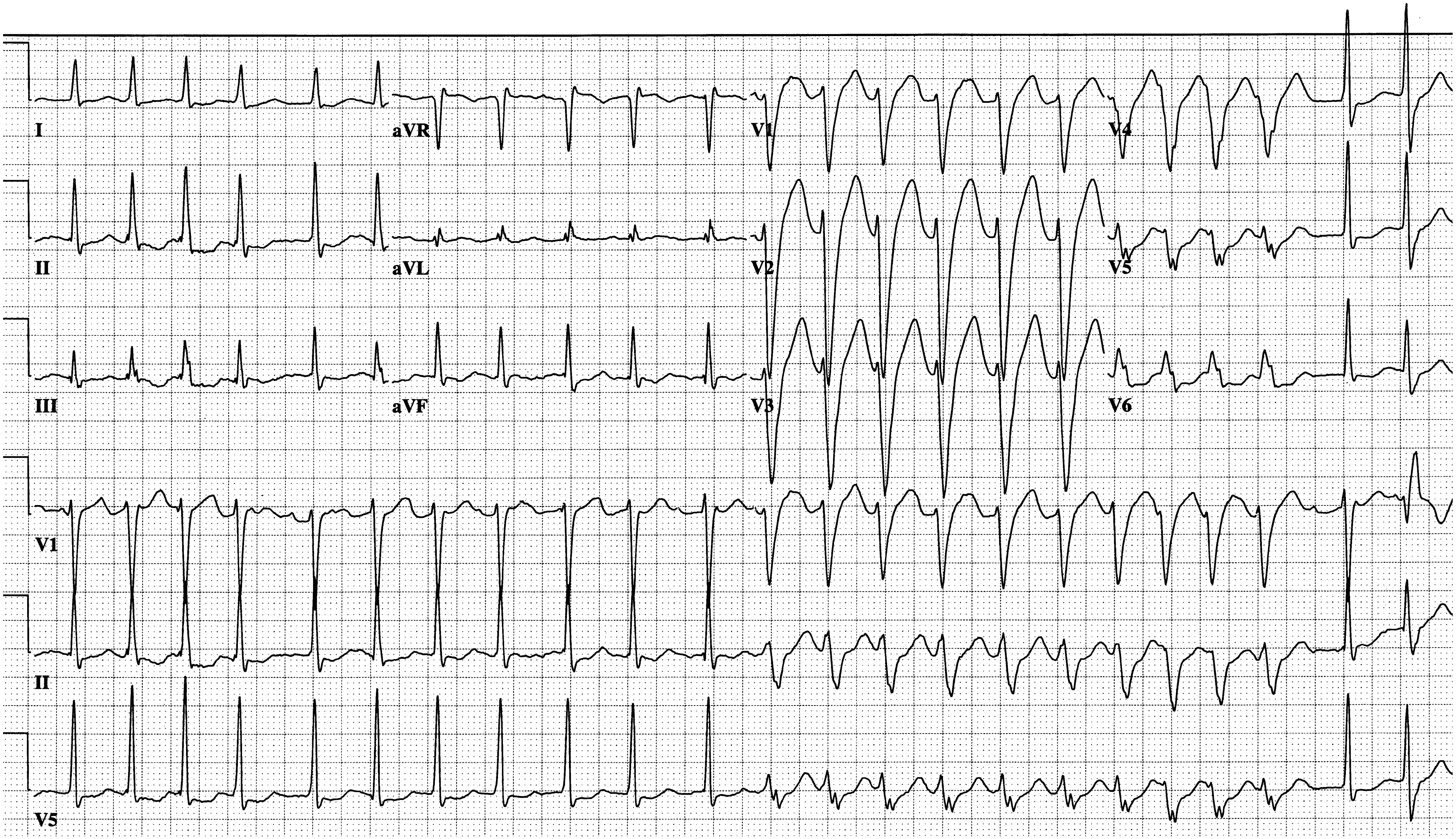
T wave: ______________

QT interval: ______________

U wave: ______________

Diagnosis: ______________

____



ECG 16

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

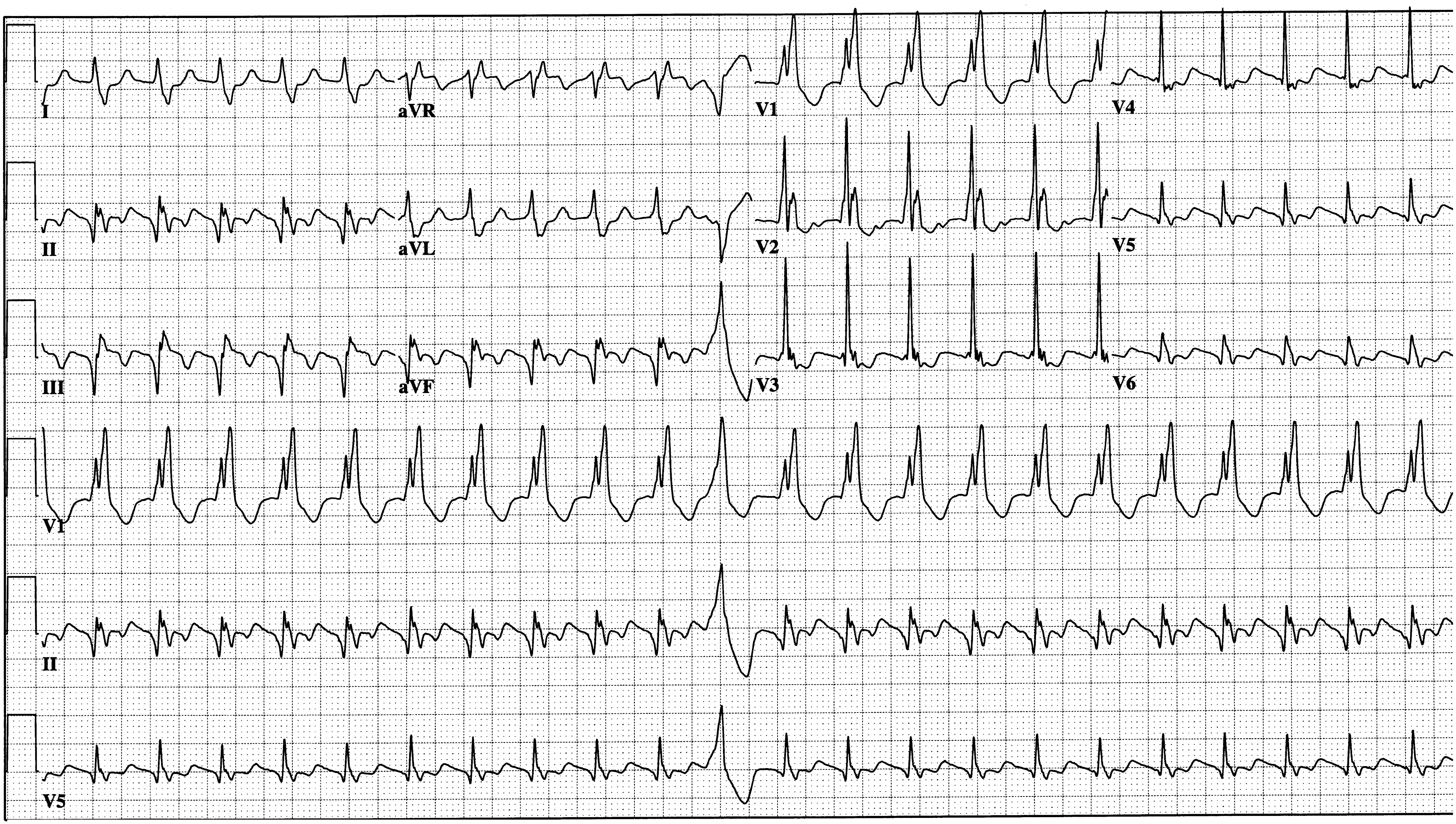
ST segment: ____________________

T wave: ____________________

QT interval: ____________________

U wave: ____________________

Diagnosis: ____________________



ECG 17

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

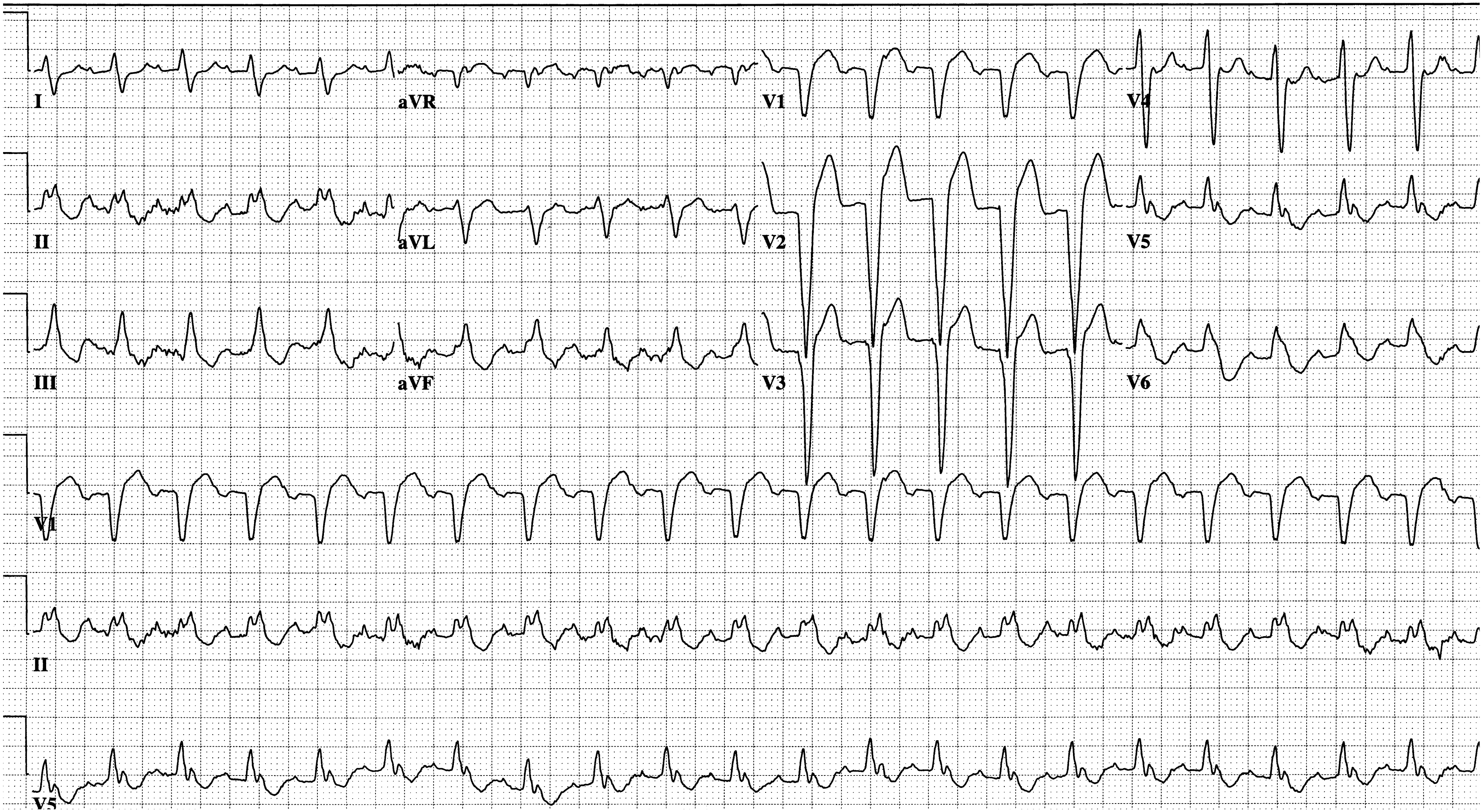
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 18

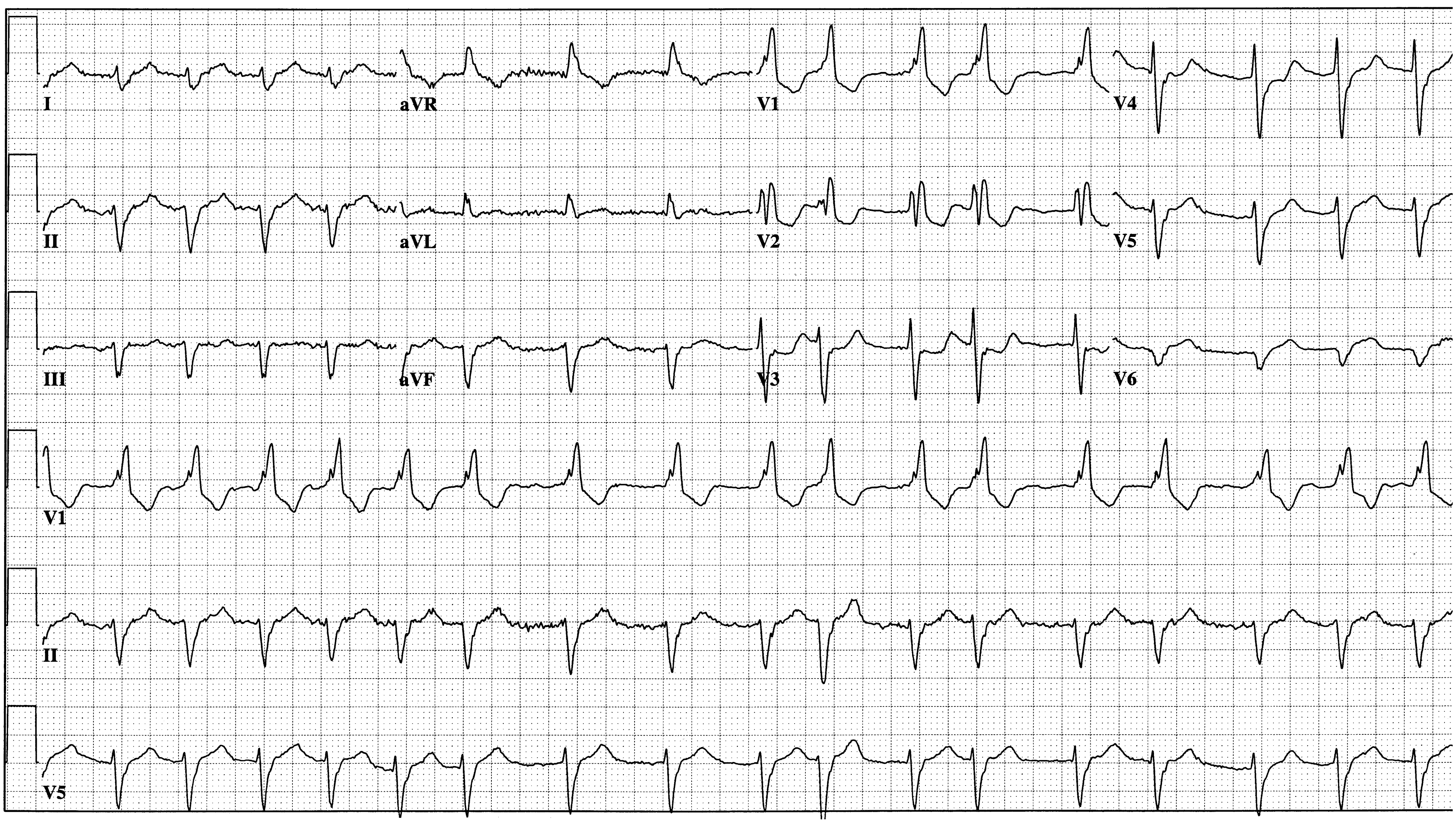
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

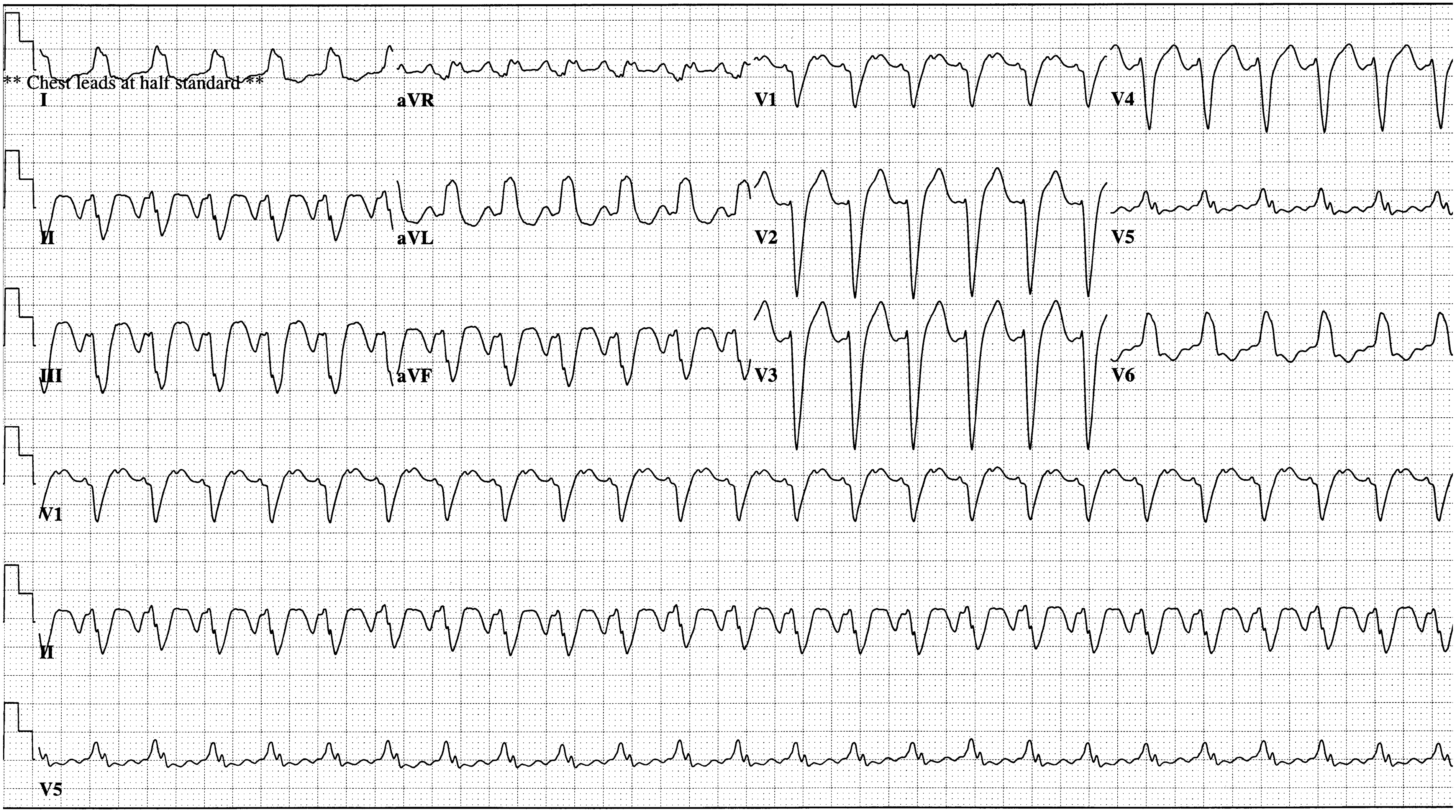
P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG 19

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG 20

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

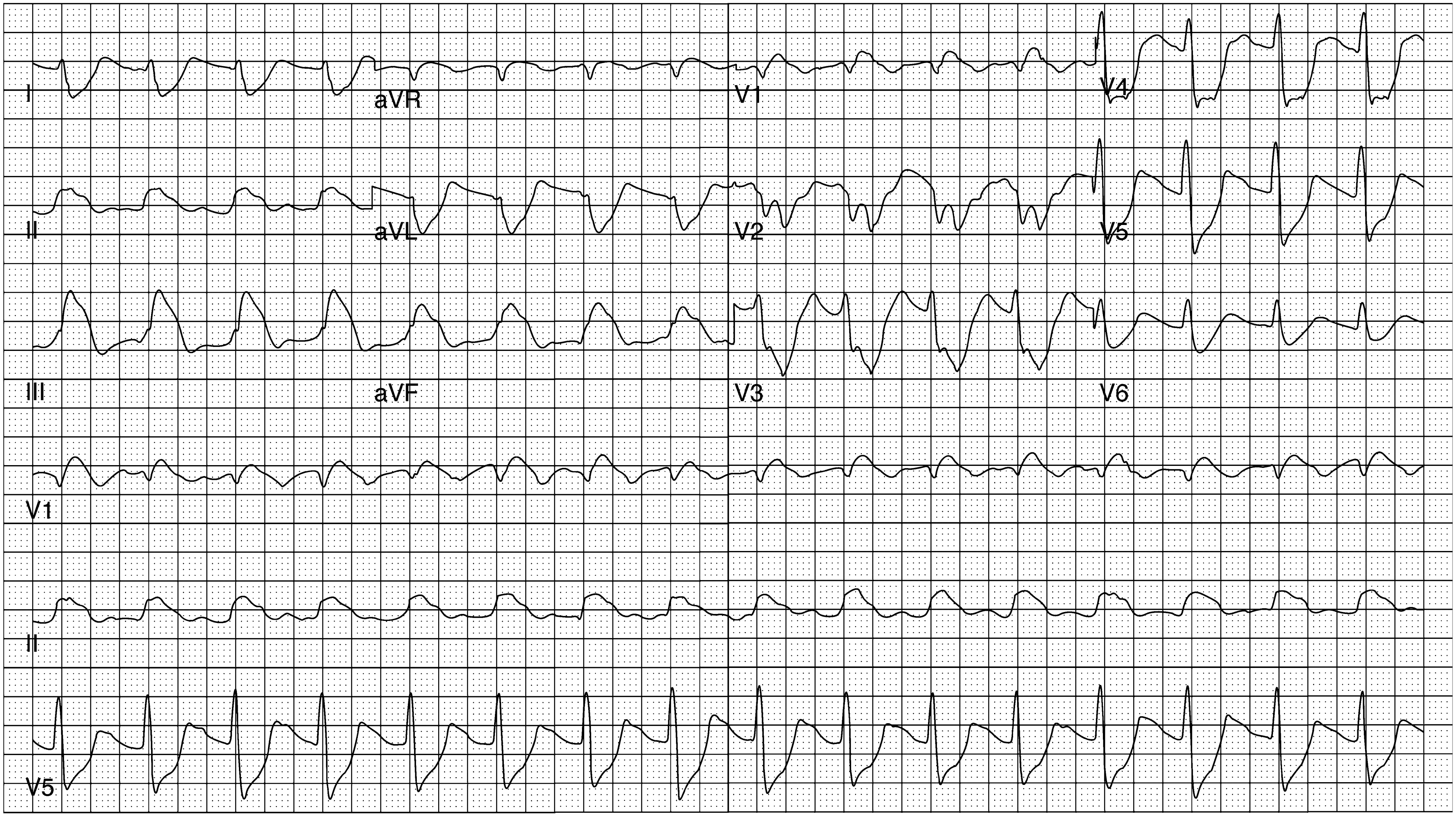
ST segment: ____________________

T wave: ____________________

QT interval: ____________________

U wave: ____________________

Diagnosis: ____________________



The Differential Diagnosis of Wide-QRS Tachycardias

Interpretations of Sample Tracings

ECG 1

Atrial rate:
Ventricular rate: 165
Rhythm: Ventricular tachycardia
P wave:
PR interval:
QRS complex:
  Axis: −90°
  Duration: 200 msec
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval: 350 msec
U wave:
Diagnosis: This is a wide complex tachycardia with perhaps a QS complex in V_1. In any case, the RS interval is >100 msec confirming the diagnosis of ventricular tachycardia.

ECG 2

Atrial rate:
Ventricular rate: 145
Rhythm: Ventricular tachycardia
P wave:
PR interval:
QRS complex:
  Axis: −45°
  Duration: 180 msec
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval: 380 msec
U wave:
Diagnosis: This is a wide complex tachycardia that has RS complexes in the precordial leads. The RS interval in V_4 is >100 msec, confirming the diagnosis of ventricular tachycardia.

ECG 3

Atrial rate: 220
Ventricular rate: 220
Rhythm: Atrial flutter with 1:1 AV conduction

P wave:
PR interval:
QRS complex:
Axis: 180°
Duration: 125 msec, RBBB
Voltage: Normal
Morphology: Normal
ST segment:
T wave:
QT interval: 200 msec
U wave:
Diagnosis: This is a wide complex tachycardia with RS complexes in the precordial leads. None of the RS intervals exceeds 100 msec. There is no evidence of AV dissociation. The presence of an RSR' configuration in V_1 strongly favors a supraventricular rhythm. The administration of intravenous adenosine subsequently proved that this was atrial flutter with 1:1 AV conduction and RBBB.

ECG 4

Atrial rate: 270
Ventricular rate: 135
Rhythm: Atrial flutter with 2:1 AV block
P wave:
PR interval:
QRS complex:
Axis: 75°
Duration: 160 msec, LBBB
Voltage:
Morphology:
ST segment:
T wave:
QT interval: 360 msec
U wave:
Diagnosis: This is a wide complex tachycardia with RS complexes in the precordial leads. None of the RS intervals are >100 msec. There are easily discernable P waves in V_1. The morphology criteria favor a supraventricular origin. The presence of the two P waves for each ventricular complex confirms the diagnosis of atrial flutter with 2:1 AV block and LBBB.

ECG 5

Atrial rate: 300
Ventricular rate: 150
Rhythm: Atrial flutter with 2:1 AV block
P wave:

PR interval:
QRS complex:
Axis: 215°
Duration: 160 msec, RBBB
Voltage:
Morphology: Q waves in II, III, aVF, I and V_6.
ST segment:
T wave:
QT interval: 310 msec
U wave:
Diagnosis: This is a wide complex tachycardia with RS complexes in the precordial leads. None of the RS complexes are >100 msec. There appears to be two P waves for every QRS complex most easily visible in the Lead II rhythm strip near the premature beat. This confirms the diagnosis of atrial flutter with 2:1 AV block and RBBB.

ECG 6

Atrial rate:
Ventricular rate: 120
Rhythm: Ventricular tachycardia
P wave:
PR interval:
QRS complex:
Axis: –90°
Duration: 160 msec
Voltage:
Morphology:
ST segment:
T wave:
QT interval: 420 msec
U wave:
Diagnosis: This is a wide QRS tachycardia with RS complexes in the precordial leads. None of the RS intervals are >100 msec. The morphology criteria support the diagnosis of ventricular tachycardia with a QS complex in V_6.

ECG 7

Atrial rate:
Ventricular rate: 160
Rhythm:
P wave:
PR interval:
QRS complex:
Axis: Right superior axis deviation
Duration: 150 msec

Voltage:
Morphology: Q waves in II, III, and aVF
ST segment:
T wave:
QT interval: 280 msec
U wave:
Diagnosis: This is a wide complex tachycardia with RS complexes in the precordial leads. None of the RS intervals is >100 msec. Atrial activity cannot be discerned. There is a hint of an RSRí complex in V_1 which favors supraventricular tachycardia; however, the R/S <1 in V_6 favors VT. This arrhythmia is probably supraventricular tachycardia with a RBBB morphology. If the latter is true then there are criteria for an old inferior MI. The rhythm could be atrial flutter with 2:1 AV block or AV nodal reentrant tachycardia (AVNRT).

ECG 8

Atrial rate:
Ventricular rate: 90
Rhythm: Idioventricular rhythm
P wave:
PR interval:
QRS complex:
Axis: 60°
Duration: 240 msec
Voltage:
Morphology:
ST segment:
T wave:
QT interval: 600 msec
U wave:
Diagnosis: This is a very wide complex rhythm with RS complexes in the precordial leads. The RS interval is much >100 msec in several leads, confirming the diagnosis of idioventricular rhythm. This patient had severe ongoing ischemia and hypotension.

ECG 9

Atrial rate: 125
Ventricular rate: 125
Rhythm: Sinus tachycardia
P wave: Normal
PR interval: 120 msec
QRS complex:
Axis: −30°
Duration: 160 msec, LBBB
Voltage:
Morphology:

ST segment:
T wave:
QT interval: 360 msec
U wave:
Diagnosis: This is a wide complex tachycardia with RS complexes in the precordial leads. None of the RS intervals is >100 msec. there are tiny P waves just visible prior to each QRS complex in V_1 and II. Morphology criteria favor a supraventricular origin. This rhythm is sinus tachycardia with LBBB.

ECG 10

Atrial rate: 52
Ventricular rate: 52
Rhythm: Sinus bradycardia with an intermittent idioventricular rhythm
P wave: Normal
PR interval: 140 msec
QRS complex:
  Axis: –60°
  Duration: 80 msec in sinus bradycardia and 120 msec in idioventricular rhythm
  Voltage: Normal
  Morphology:
ST segment:
T wave:
QT interval: 590 msec
U wave:
Diagnosis: Sinus bradycardia with an intermittent idioventricular rhythm. The sinus P wave can be seen coming later and later after each QRS complex during the idioventricular rhythm. In this case, there is AV dissociation but no changes in AV nodal conduction.

ECG 11

Atrial rate:
Ventricular rate: 140
Rhythm: Ventricular tachycardia
P wave:
PR interval:
QRS complex:
  Axis: Right superior axis deviation
  Duration: 160 msec
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval: 330 msec
U wave:

Diagnosis: This is a wide complex tachycardia with RS complexes in the precordial leads. The RS intervals are close to but do not exceed 100 msec. The monophasic R wave in V_1 and the R/S <1 in V_6 suggests ventricular tachycardia.

ECG 12

Atrial rate:
Ventricular rate: 155
Rhythm:
P wave:
PR interval:
QRS complex:
  Axis: −60°
  Duration: 125 msec
  Voltage: Increased in aVL and the precordial leads
  Morphology: Delayed precordial transition
ST segment:
T wave:
QT interval: 300 msec
U wave:
Diagnosis: This is a wide complex tachycardia with RS complexes in the precordial leads. None of the RS complexes exceeds 100 msec. There is no evidence of atrial activity. The RS interval in V_1 is much <60 msec, suggesting a supraventricular origin however, there is a QR complex in V_6 consistent with ventricular tachycardia. Brugadaís criteria are therefore equivocal. The QRS duration barely exceeding 120 msec favors a supraventricular tachycardia, most likely atrial flutter with 2:1 AV block. The single wide complex beat in the last part of the tracing has a different morphology than the rest and occurs earlier, suggesting that this is an isolated PVC in the midst of a supraventricular rhythm.

ECG 13

Atrial rate: 65
Ventricular rate: 101
Rhythm: Sinus rhythm with first degree AV block and nonsustained ventricular tachycardia
P wave: Normal
PR interval: 220 msec
QRS complex:
  Axis: −75°
  Duration: 130 msec, RBBB
  Voltage: Normal
  Morphology: Normal
ST segment:
T wave:
QT interval: 370 msec
U wave:

Diagnosis: Sinus rhythm with first degree AV block, left axis deviation, RBBB and frequent PVCs once occurring as an episode of nonsustained ventricular tachycardia. AV dissociation can be identified during the ventricular tachycardia.

ECG 14

Atrial rate: Probably 220
Ventricular rate: 220
Rhythm: Probably atrial flutter with 1:1 AV conduction
P wave:
PR interval:
QRS complex:
  Axis: 130°
  Duration: 200 msec
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval: 290 msec
U wave:
Diagnosis: This is a wide complex tachycardia with RS complexes in the precordial leads. None of the RS intervals is >100 msec. There is a suggestion of flutter waves in III and aVF. The QR complex in V_1 favors ventricular tachycardia, but the R/S of >1 in V_6 favors supraventricular tachycardia. The most likely diagnosis is atrial flutter with 1:1 AV conduction and RBBB.

ECG 15

Atrial rate:
Ventricular rate: 140
Rhythm: Atrial fibrillation with rapid ventricular response and occasional aberrant conduction
P wave:
PR interval:
QRS complex:
  Axis: 60°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 350 msec
U wave:
Diagnosis: Atrial fibrillation with rapid ventricular response with an episode of wide complex beats. The rhythm is irregular during this episode and the rate is faster than the rest of the ECG, implying that this is atrial fibrillation with a LBBB aberrancy.

ECG 16

Atrial rate: 270
Ventricular rate: 135
Rhythm: Atrial flutter with 2:1 AV block
P wave:
PR interval:
QRS complex:
  Axis: 60°
  Duration: 160 msec, RBBB
  Voltage: Normal
  Morphology: Q waves in II, III, aVF, V_5, and V_6
ST segment:
T wave:
QT interval: 340 msec
U wave:
Diagnosis: This is a wide complex tachycardia with RS complexes in the precordial leads. None of the RS intervals is >100 msec. Flutter waves can be discerned in II and aVF. The morphology criteria favor a supraventricular tachycardia. This rhythm is atrial flutter with 2:1, RBBB, AV block and evidence of an old inferolateral MI.

ECG 17

Atrial rate: 130
Ventricular rate: 130
Rhythm: Sinus tachycardia with first degree AV block
P wave: Normal
PR interval: 240 msec
QRS complex:
  Axis: 100°
  Duration: 150 msec
  Voltage: Normal
  Morphology: Normal
ST segment:
T wave:
QT interval: 300 msec
U wave:
Diagnosis: This is a wide complex tachycardia with RS complexes in the precordial leads. None of the RS intervals are >100 msec. A single sinus P wave can be seen preceding each QRS complex in V_1. The morphology criteria favor a supraventricular origin. This is sinus tachycardia with a nonspecific IVCD.

ECG 18

Atrial rate:
Ventricular rate: 105

Rhythm: Atrial fibrillation with rapid ventricular response
P wave:
PR interval:
QRS complex:
  Axis: Right superior axis deviation
  Duration: 140 msec, RBBB
  Voltage: Normal
  Morphology: Q waves in V_6
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 380 msec
U wave:
Diagnosis: This is a wide complex tachycardia with obvious irregularities in the RR intervals consistent with atrial fibrillation with RBBB. There is also right superior axis deviation and a possible old lateral MI.

ECG 19

Atrial rate: 290
Ventricular rate: 145
Rhythm: Atrial flutter with 2:1 AV block
P wave:
PR interval:
QRS complex:
  Axis: −60°
  Duration: 150 msec
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval: 310 msec
U wave:
Diagnosis: This is a wide complex tachycardia with RS complexes in the precordial leads. None of the RS intervals are >100 msec. Two P waves for each QRS complex can be discerned in V_1. The monophasic R wave in V_6 favors a supraventricular origin. The rhythm is therefore atrial flutter with 2:1 AV block and LBBB.

ECG 20

Atrial rate:
Ventricular rate: 100
Rhythm: Idioventricular rhythm
P wave:
PR interval:

QRS complex:
Axis: 45°
Duration: 260 msec
Voltage:
Morphology:
ST segment: Profound diffuse ST segment depression in most leads with ST segment elevation in II, III, and aVF.
T wave:
QT interval: 440 msec
U wave:
Diagnosis: This ECG is included as an example of idioventricular rhythm following an episode of cardiac arrest and resuscitation. There is evidence of a probably acute inferior MI.

Day 9

Medication and Electrolyte Effects; Miscellaneous Conditions

I. Medication effects

A. Digoxin (Day 9-01)
1. Digoxin has a narrow therapeutic to toxic ratio, and is potent stimulator of arrhythmias.
2. At therapeutic levels, digoxin frequently causes nonspecific ST changes with "scooping" of the ST segment and shortening of the QT interval.
3. Digoxin causes SA nodal suppression and AV block.
4. Digoxin can cause virtually any arrhythmia, but, because of its ability to enhance *automaticity*, ectopic arrhythmias are commonly encountered in digoxin toxicity.
5. The commonest arrhythmia manifested by digoxin toxicity is multiform PVCs. (Day 9-02)
6. The two most specific arrhythmias are accelerated junctional rhythm and atrial tachycardia with AV block. (Day 9-03) (Day 9-04)

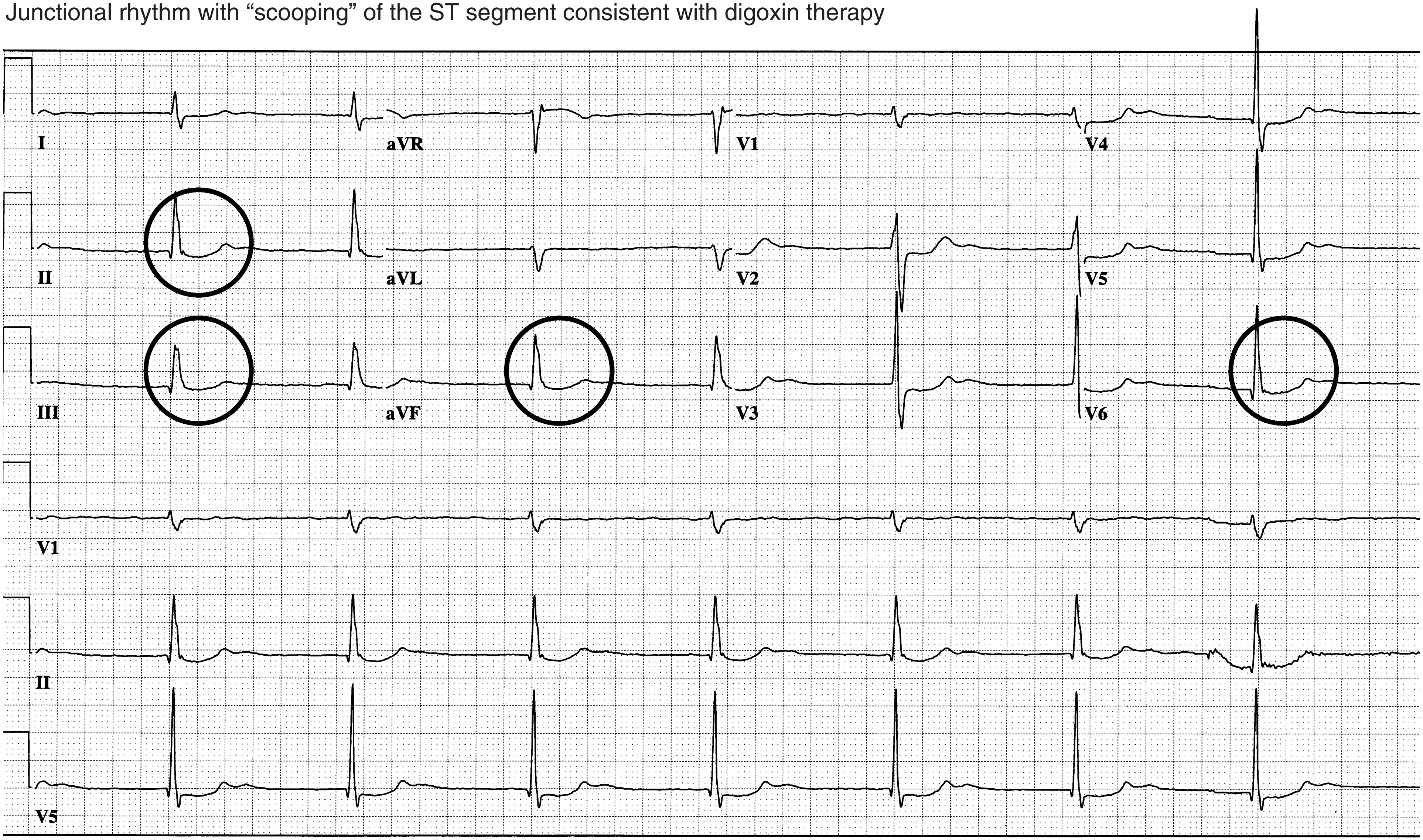
B. Sotalol and amiodarone (Day 9-05)
1. These agents slow conduction in general and result in bradycardia and prolongation of the PR, QRS, and QT intervals.
2. Sotalol also has significant beta blocking properties, which exacerbates the bradyarrhythmic effects.
3. Sotalol can also prolong the QT interval and cause *torsades de pointe*.

C. Quinidine and other Class IA agents (see long QT below)
1. These agents are less frequently used than previously because of side effects, proarrhythmic potential, and possibly increased mortality.
2. Quinidine prolongs the QRS duration and QT interval, and may cause *torsades de pointe*. (Day 6-11)

D. Verapamil and diltiazem
1. These agents can cause sinus bradycardia, varying amounts of AV block, and, in toxic doses, intraventricular conduction defects. (Day 9-06)
2. Their effects are additive with beta blockers.

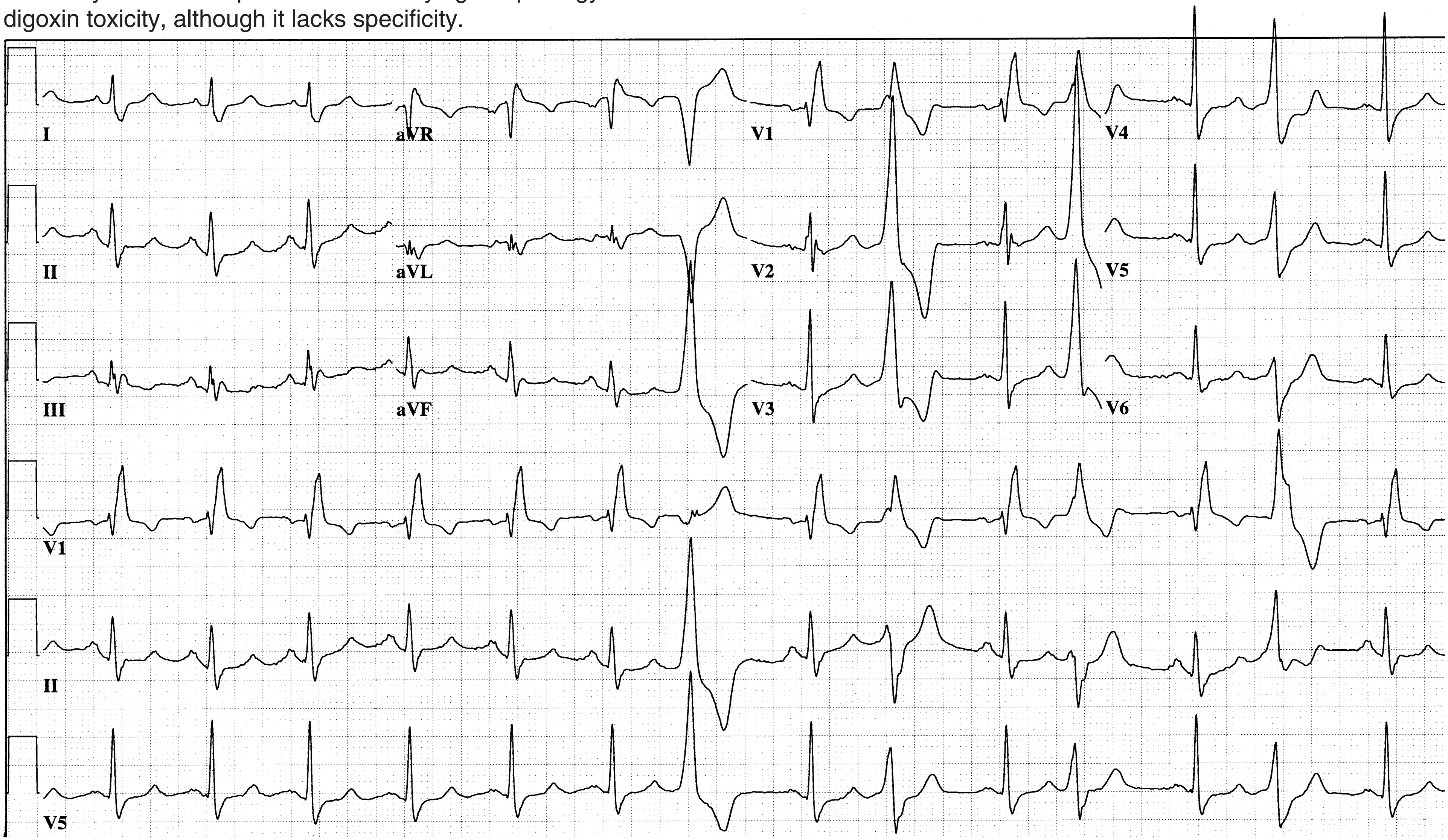
DAY 9-01

Junctional rhythm with "scooping" of the ST segment consistent with digoxin therapy



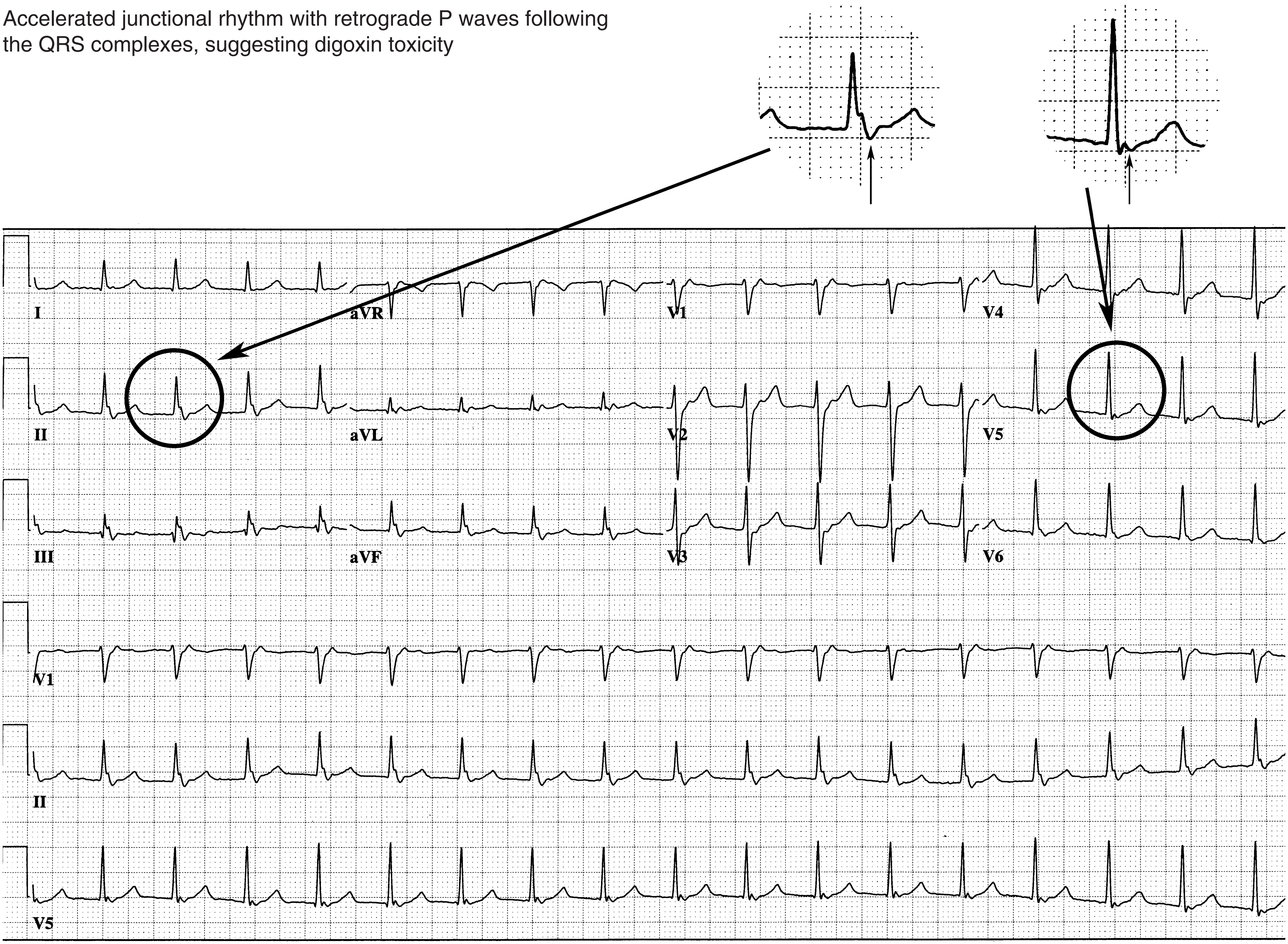
DAY 9-02

Sinus rhythm with frequent PVCs of varying morphology. This is the most common manifestation of digoxin toxicity, although it lacks specificity.



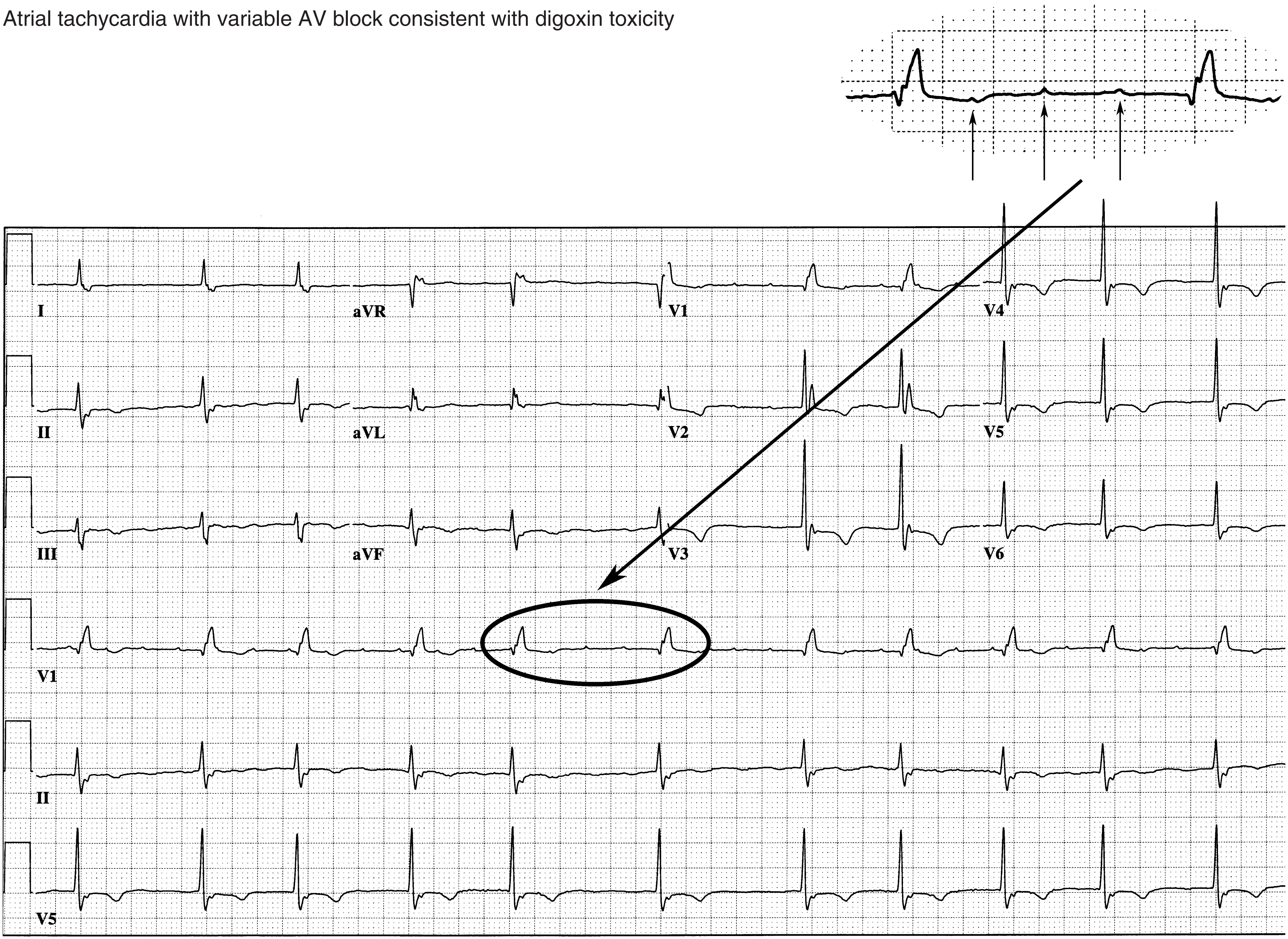
DAY 9-03

Accelerated junctional rhythm with retrograde P waves following the QRS complexes, suggesting digoxin toxicity



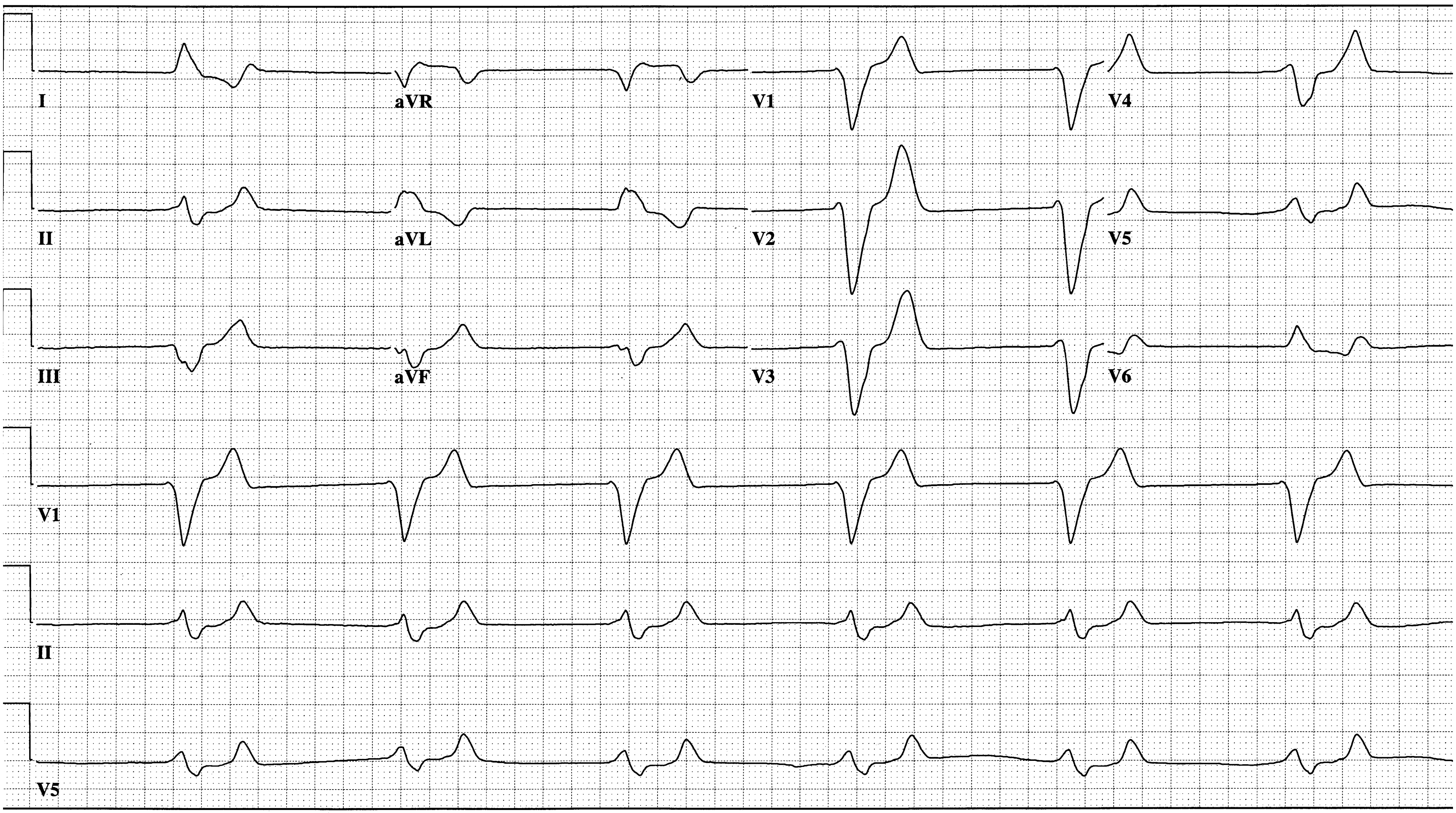
DAY 9-04

Atrial tachycardia with variable AV block consistent with digoxin toxicity



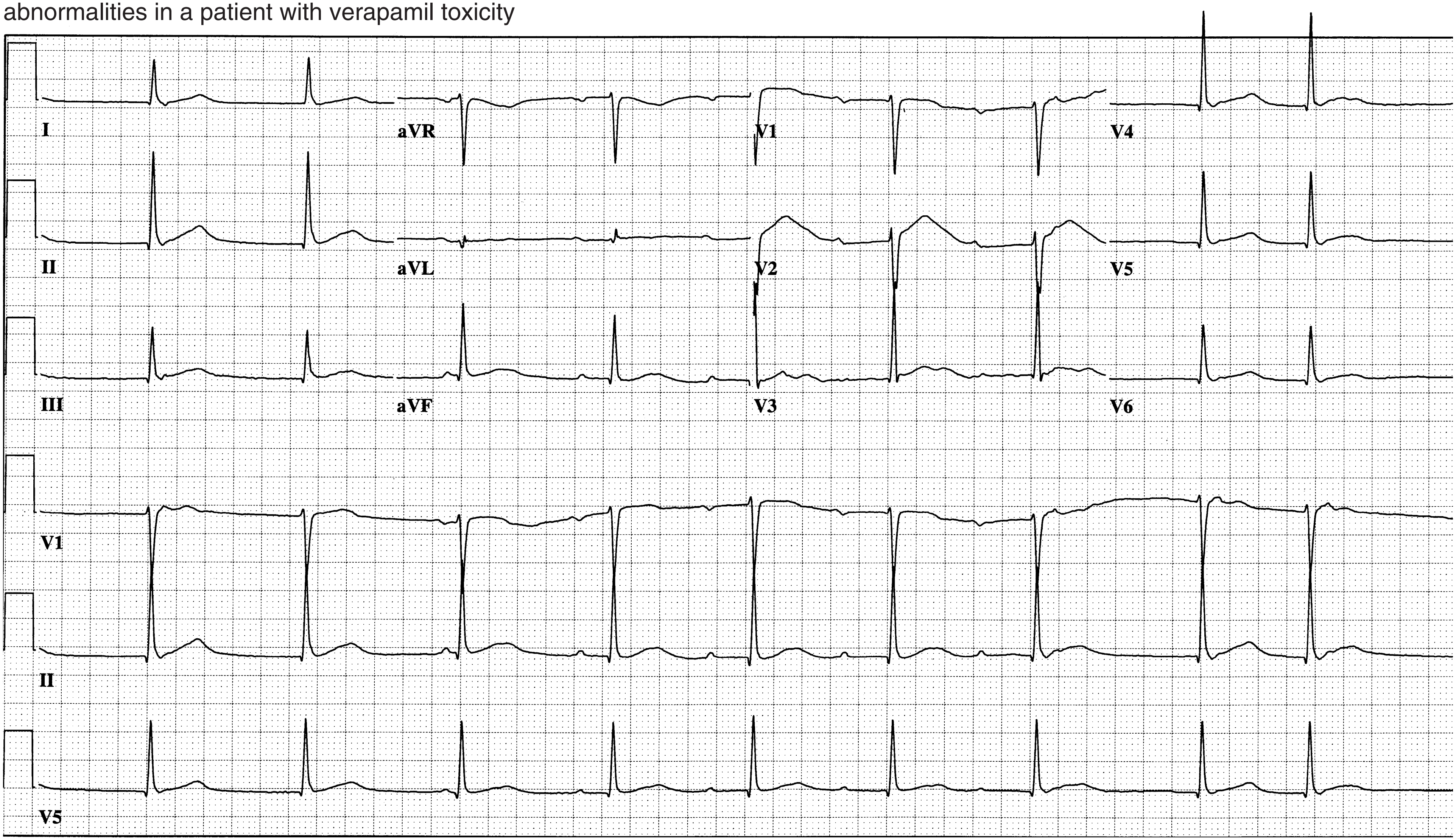
DAY 9-05

Junctional (or possibly idioventricular) rhythm with an extremely wide QRS complex in this patient with sotalol toxicity



DAY 9-06

Sinus rhythm with varying amounts of AV block, a competing junctional pacemaker, and diffuse ST-T wave abnormalities in a patient with verapamil toxicity



II. Electrolyte abnormalities

A. Hypokalemia
1. Hypokalemia potentiates a variety of arrhythmias, including VT and torsade de pointes.
2. Hypokalemia is associated with ST segment depression, a prolonged QT interval, and a prominent U wave. (Day 9-07) (Day 9-08)

B. Hyperkalemia
1. Hyperkalemia is manifested by peaked T waves, loss of obvious P waves or prolongation of the PR segment, and prolongation of the QRS complex. (Day 9-09) (Day 9-10)
2. When potassium levels reach 8–9 mmol/l, the ECG may resemble a sine wave; further elevation may cause asystole. (Day 9-11) (Day 9-12)

C. Hypocalcemia is manifested by prolongation of the QT interval; the ST segment is usually flat and the T wave is not distorted (see figure). (Day 9-13)

D. Hypercalcemia is associated with a short QT interval.

III. QT prolongation and U wave abnormalities

A. A rough indicator of QT prolongation is that the QT interval should not exceed one half of the surrounding R-R interval.

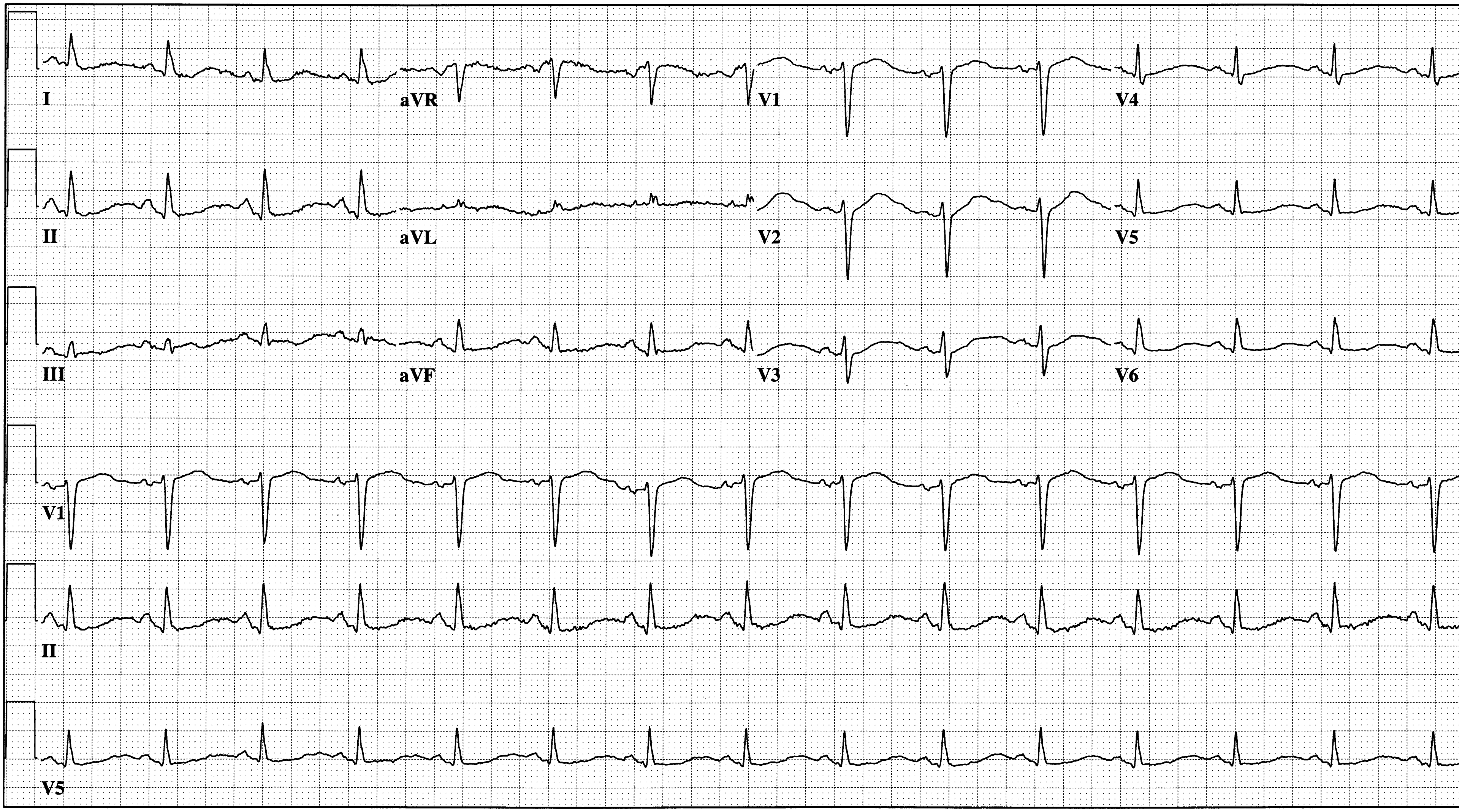
B. Congenital long QT syndromes
1. There are at least five forms of congenital long QT syndromes, two of which are:
   a. Jervell and Lange-Nielsen syndrome is an autosomal recessive disorder associated with deafness.
   b. Romano-Ward is an autosomal dominant disorder.

C. Acquired long QT syndromes
1. Non-drug causes of long QT interval include ischemia, central nervous system (CNS) lesions, and significant bradyarrhythmias. (Day 9-14) (Day 9-15)
2. Many drugs can prolong the QT interval, including the Class IA, IC, and III antiarrhythmic agents, erythromycin, some antihistamines, and some psychiatric drugs.

D. U wave abnormalities
1. Prominent U waves are seen with hypokalemia, digoxin, LVH, and amiodarone (see previous page)
2. Negative U waves are encountered in hypertension (HTN), aortic and mitral disease, and ischemia.

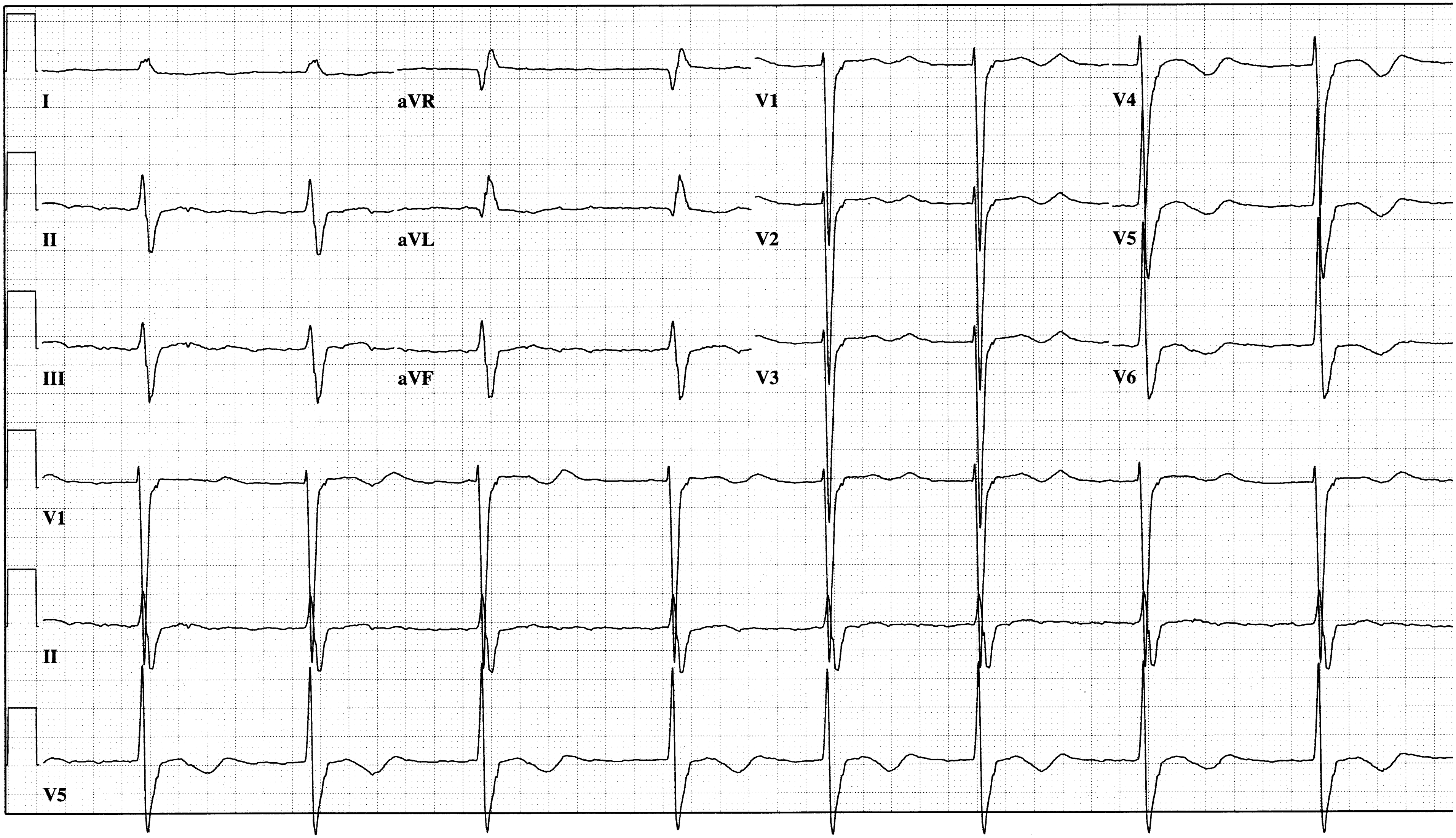
DAY 9-07

Sinus rhythm with an extremely long QT interval in a patient with severe hypokalemia (k = 1.8 mml/l)



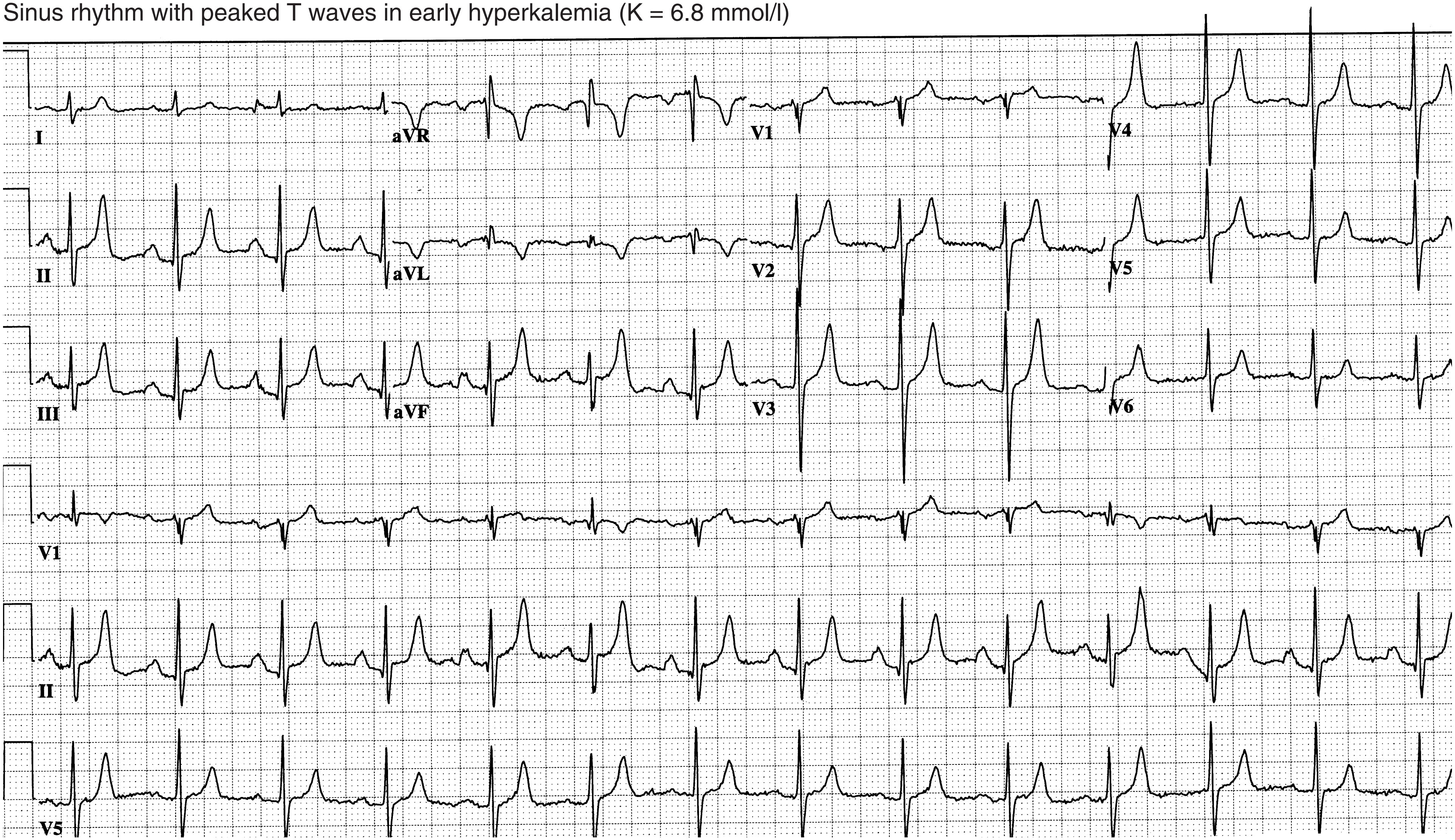
DAY 9-08

Junctional rhythm with diffuse nonspecific ST segment and T wave changes and prominent U waves in a patient with severe hypokalemia (K = 2.1 mmol/l)



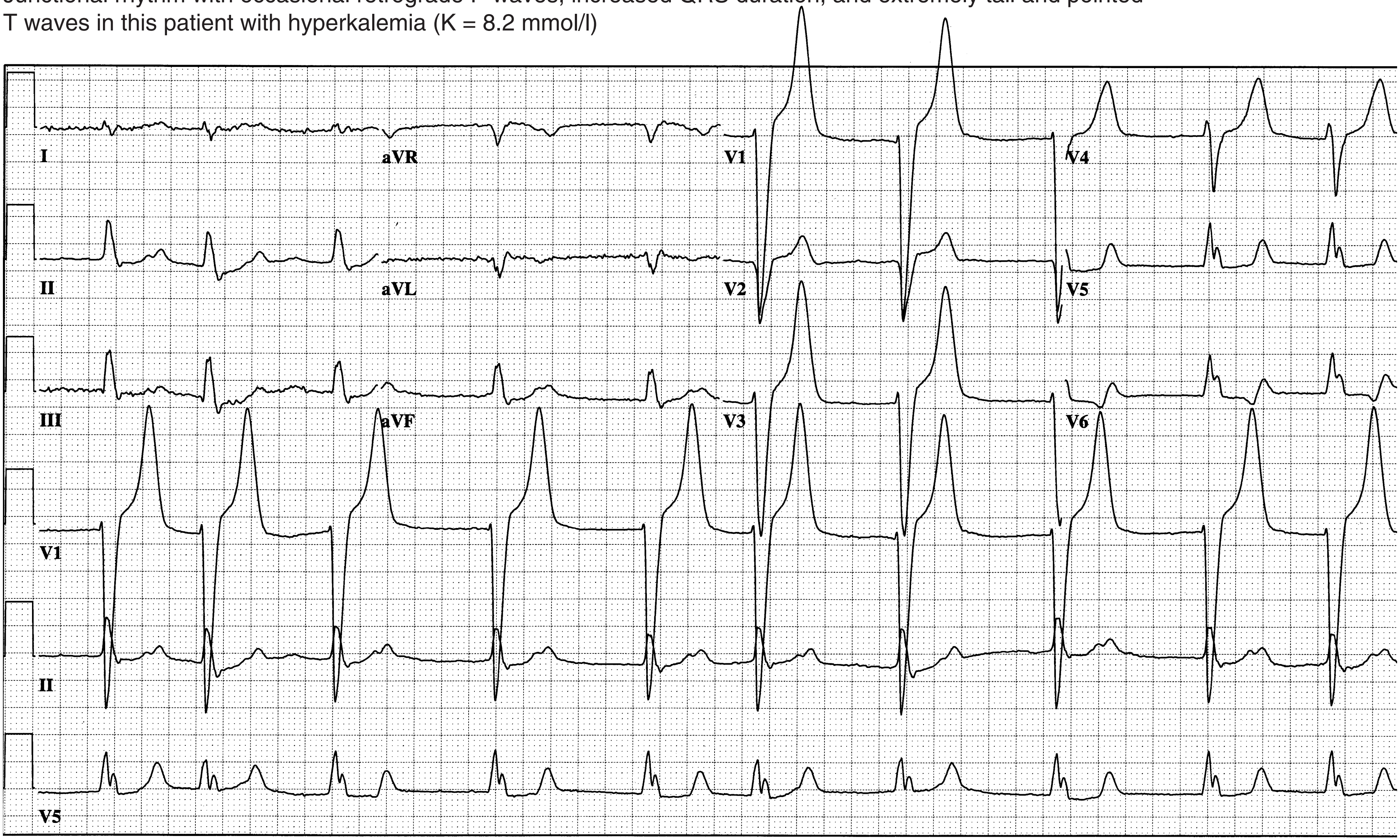
DAY 9-09

Sinus rhythm with peaked T waves in early hyperkalemia (K = 6.8 mmol/l)



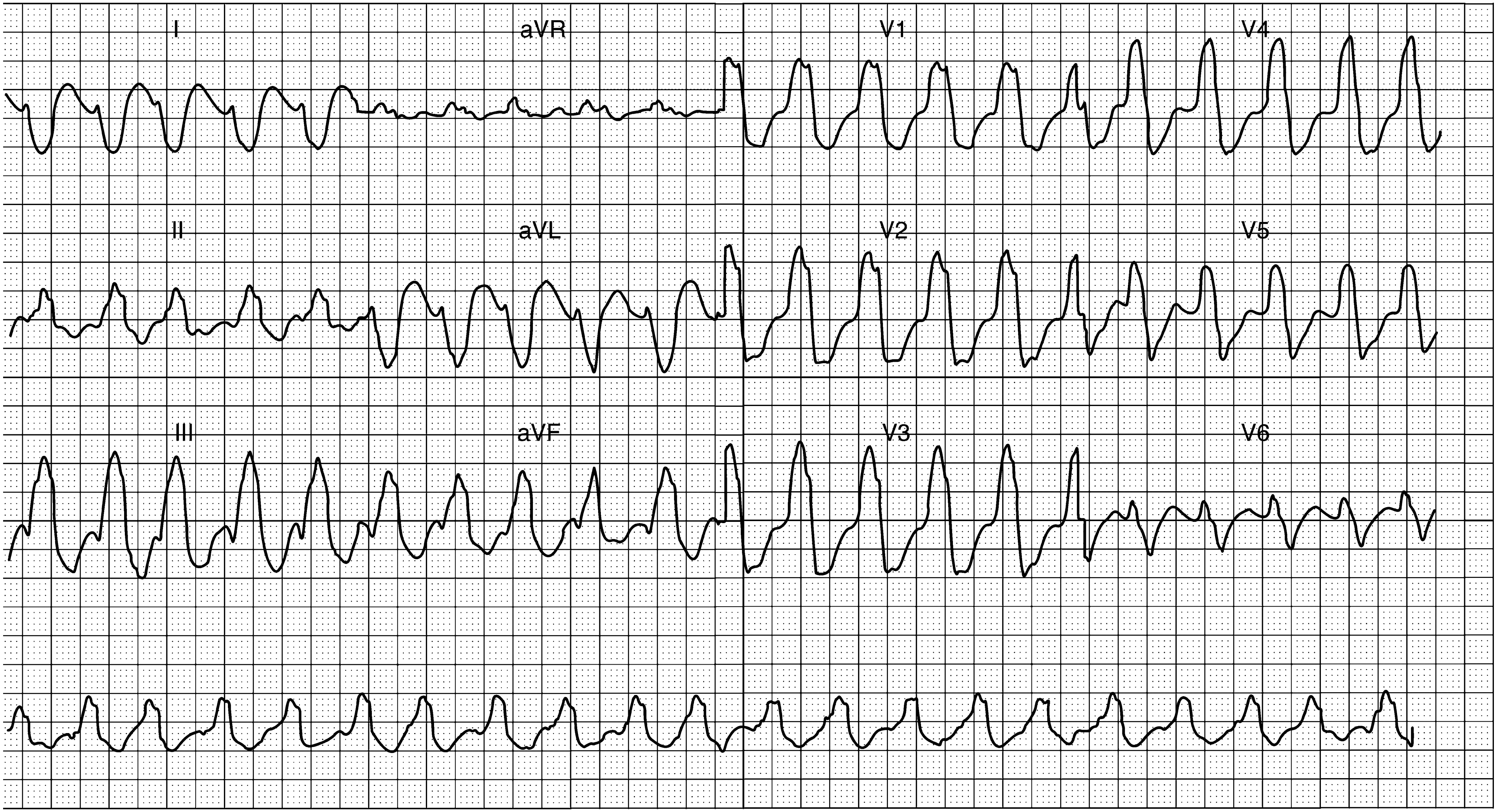
DAY 9-10

Junctional rhythm with occasional retrograde P waves, increased QRS duration, and extremely tall and pointed T waves in this patient with hyperkalemia (K = 8.2 mmol/l)



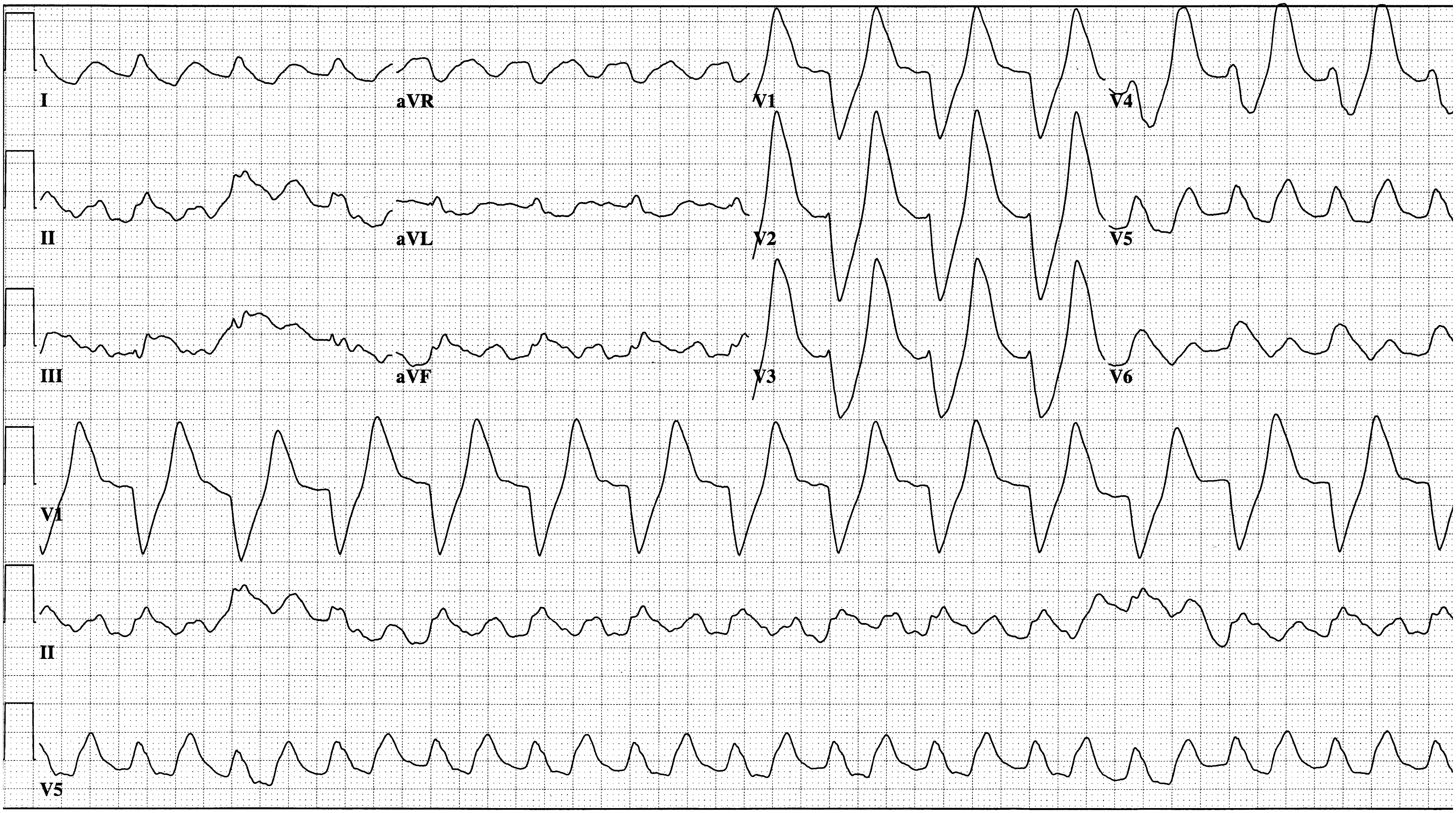
DAY 9-11

A wide complex tachycardia in a patient with severe hyperkalemia (K = 8.4 mmol/l)



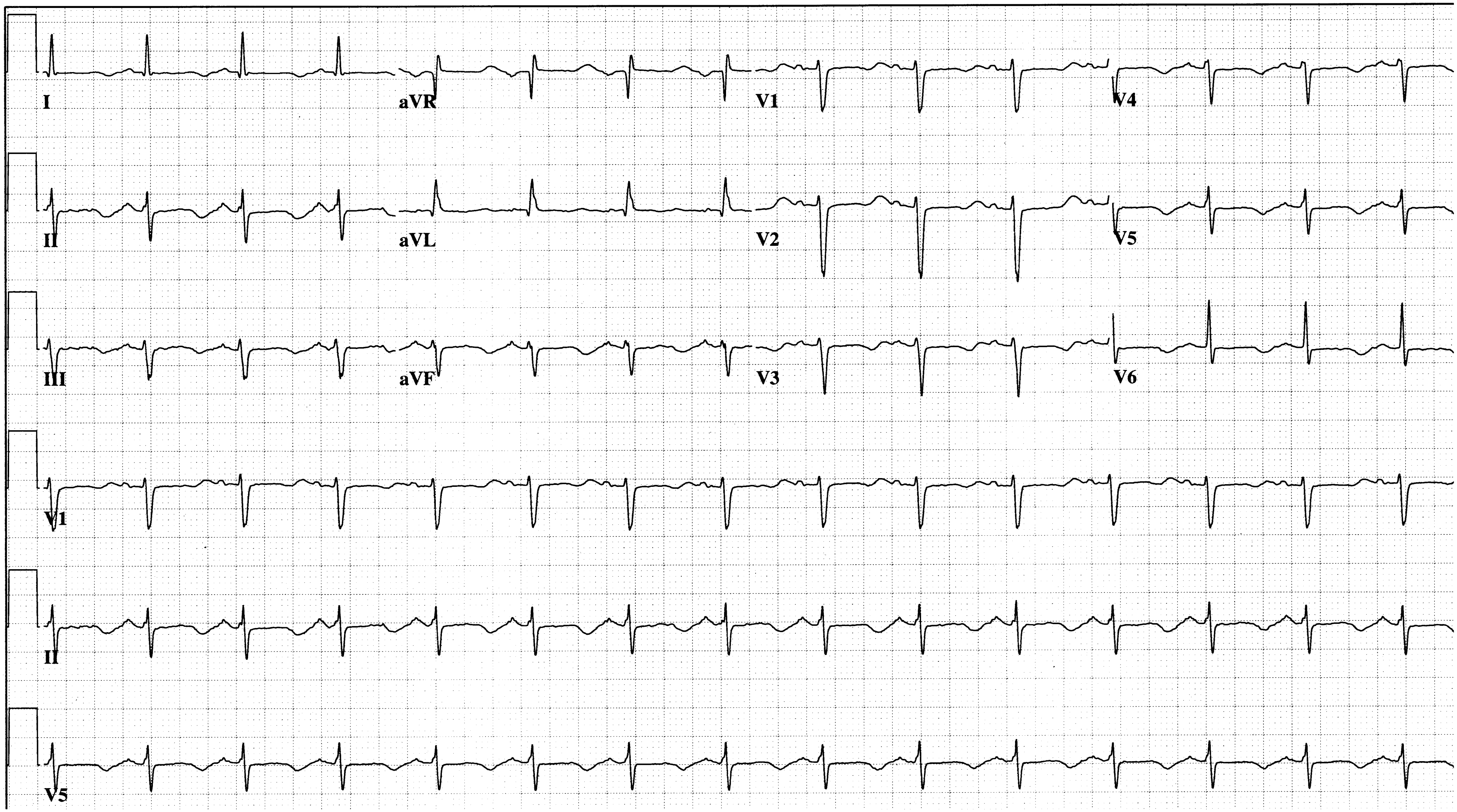
DAY 9-12

A sinusoidal rhythm in a patient with severe hyperkalemia and acidosis



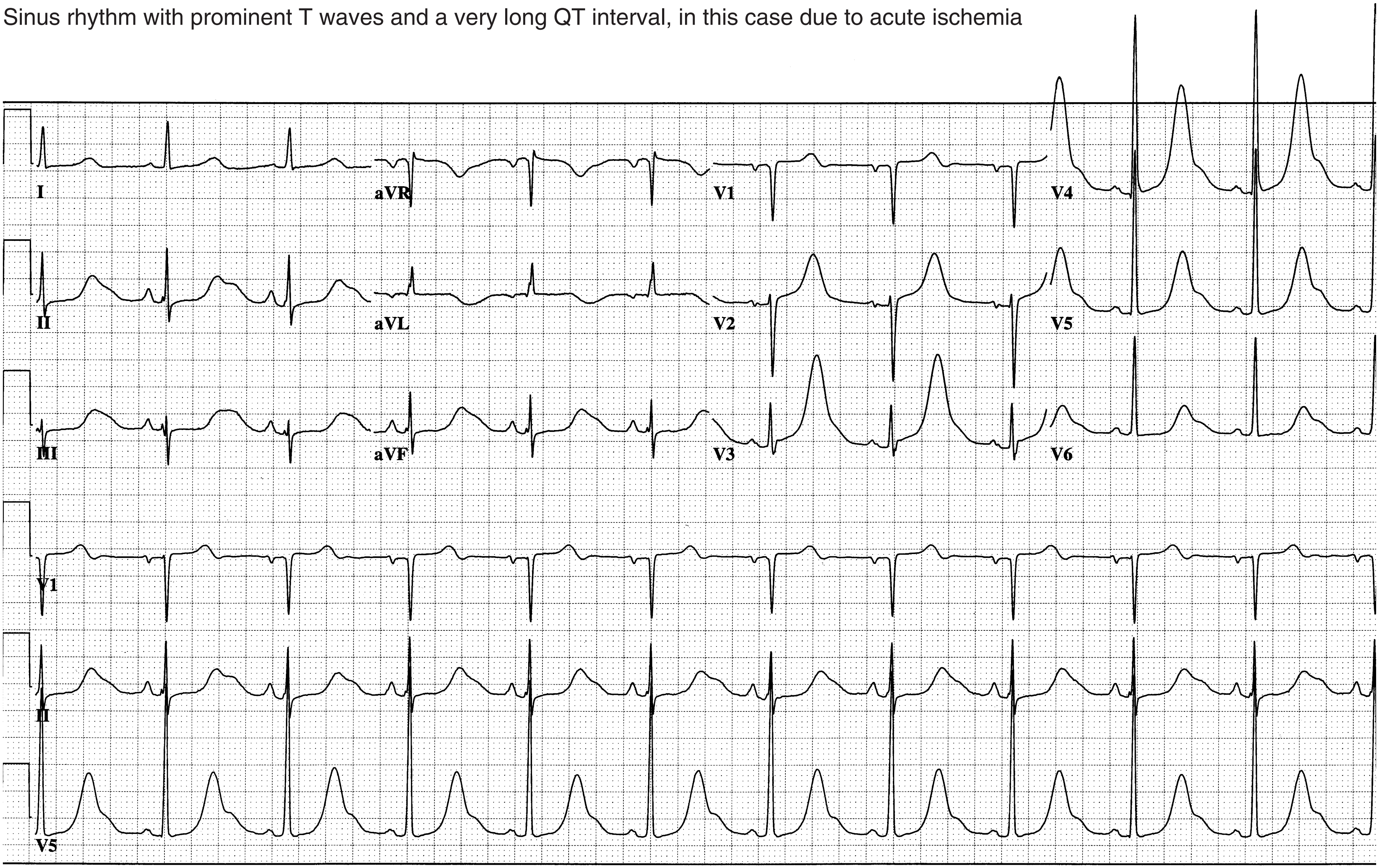
DAY 9-13

Sinus rhythm with a very long QT interval. The ST segment is flat and the T wave is fairly narrow in this patient with pancreatitis and severe hypocalcemia.



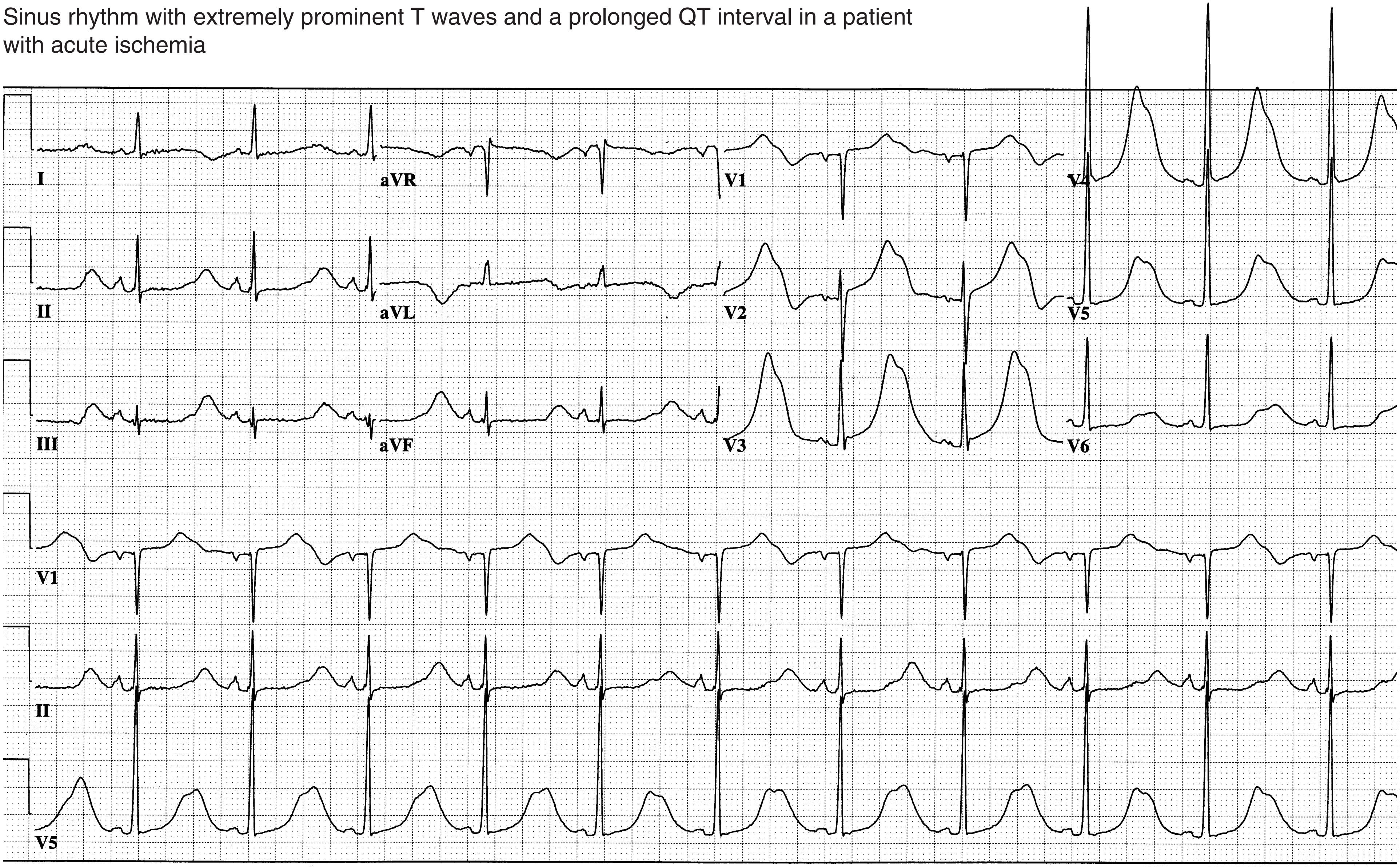
DAY 9-14

Sinus rhythm with prominent T waves and a very long QT interval, in this case due to acute ischemia



DAY 9-15

Sinus rhythm with extremely prominent T waves and a prolonged QT interval in a patient with acute ischemia



IV. Causes of tall R waves in V_1

A. Right ventricular hypertrophy (RVH) (Day 9-16)

B. Posterior MI (Day 9-17)

C. RBBB (Day 9-18)

D. Wolff-Parkinson-White (WPW) (Day 9-19)

E. Hypertrophic obstructive cardiomyopathy (HOCM) with asymmetric septal hypertrophy (ASH) (Day 9-20)

F. Congenital dextrocardia (Day 9-21)

G. Duchenne's muscular dystrophy (Day 9-22)

V. Causes of ST segment elevation

A. Acute myocardial injury (Day 9-23)

B. Left ventricular aneurysm (Day 9-24)

C. Early repolarization (Day 9-25)

D. Acute pericarditis (Day 9-26)

E. LVH (Day 9-27)

F. LBBB (Day 9-28)

G. Hyperkalemia (Day 9-29)

H. Hypothermia (Day 9-30)

I. Scorpion sting! (Day 9-31)

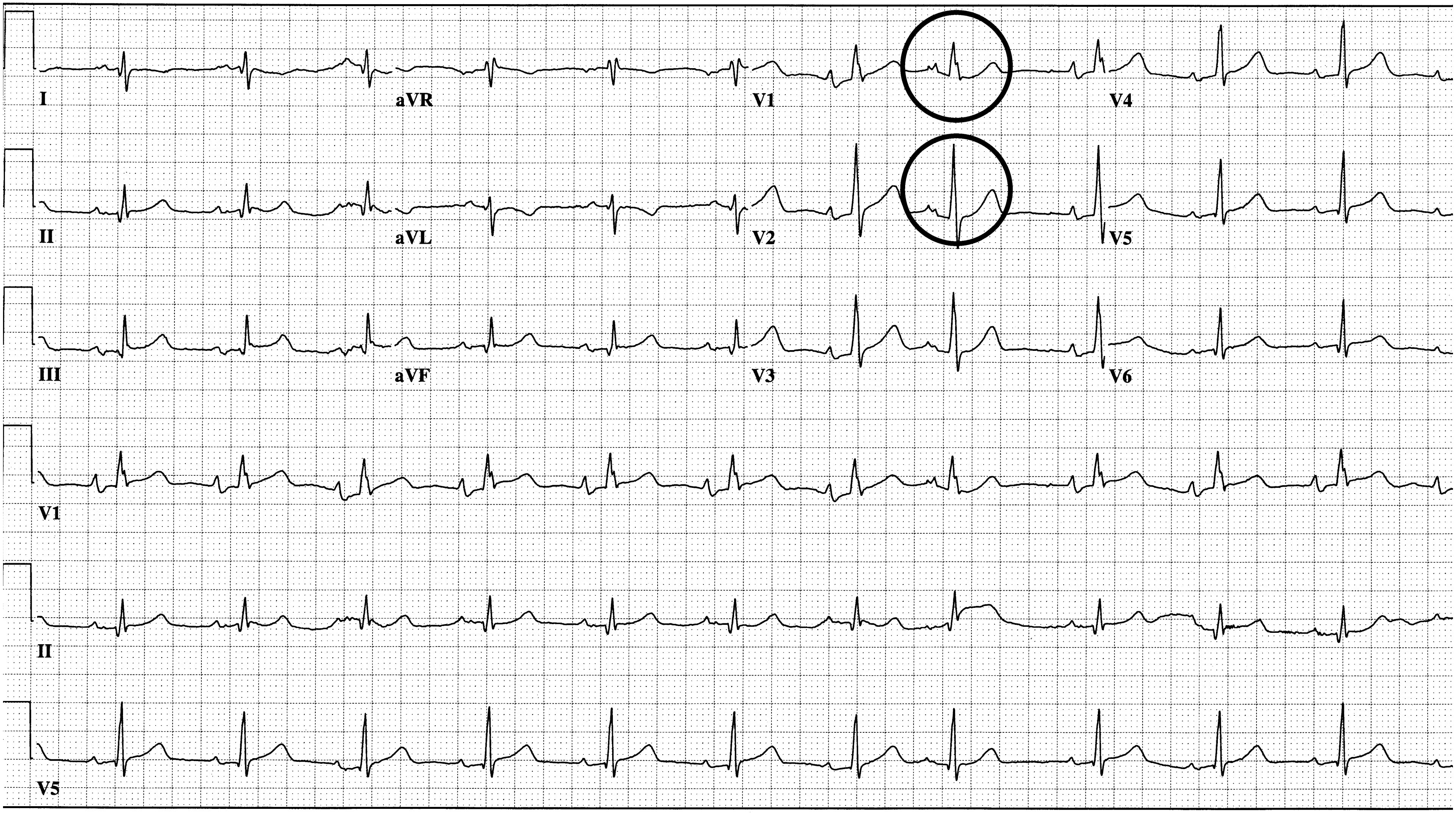
VI. CNS injury and the ECG

A. Severe acute CNS lesions, typically subarachnoid hemorrhage, are occasionally associated with ST segment and T wave changes. (Day 9-32) (Day 9-33)

B. The most likely explanation for these changes is unilateral perturbation of the sympathetic ganglia at the base of the brain.

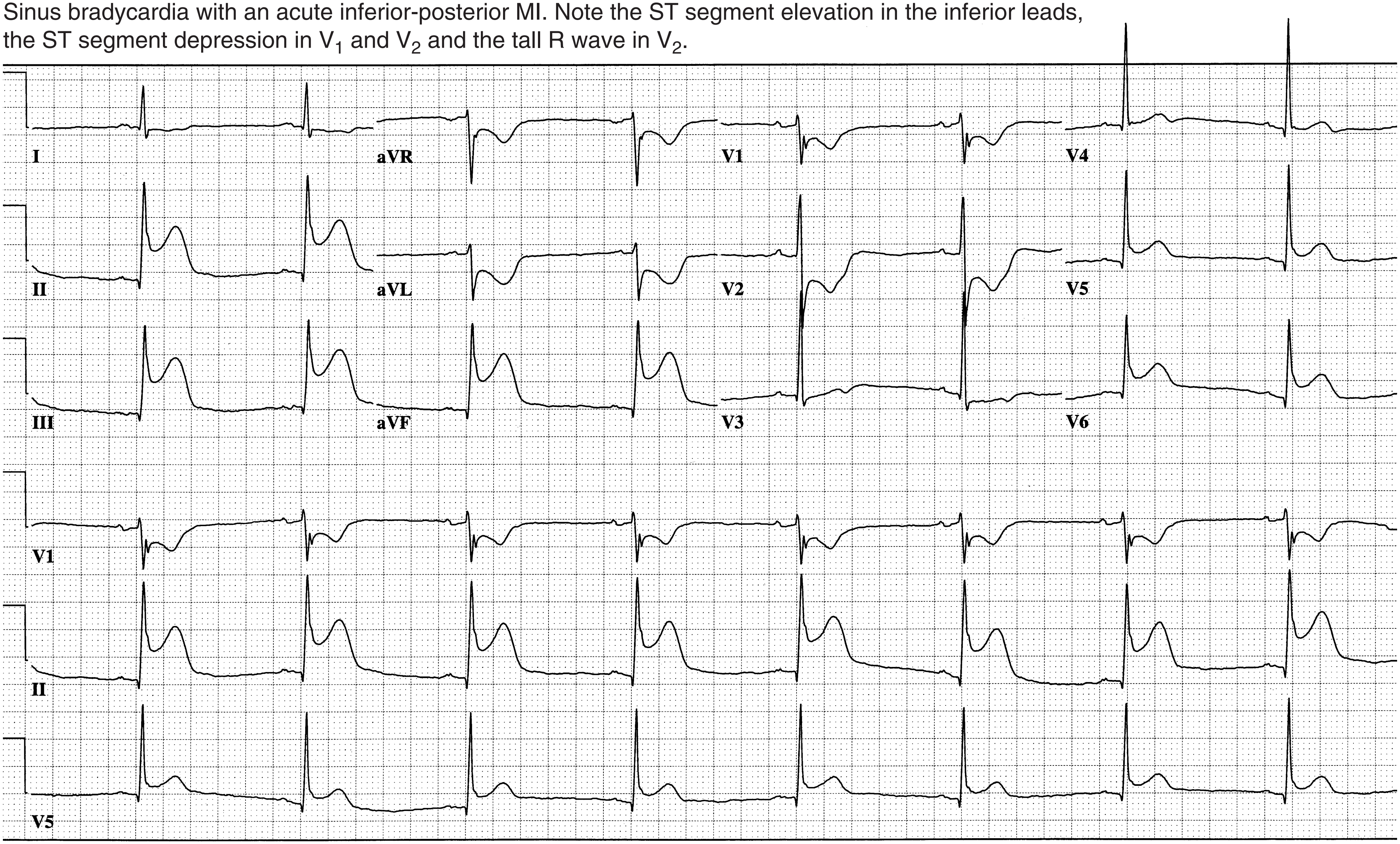
DAY 9-16

Sinus rhythm, right axis deviation, and tall R waves in the early precordial leads in a patient with RVH



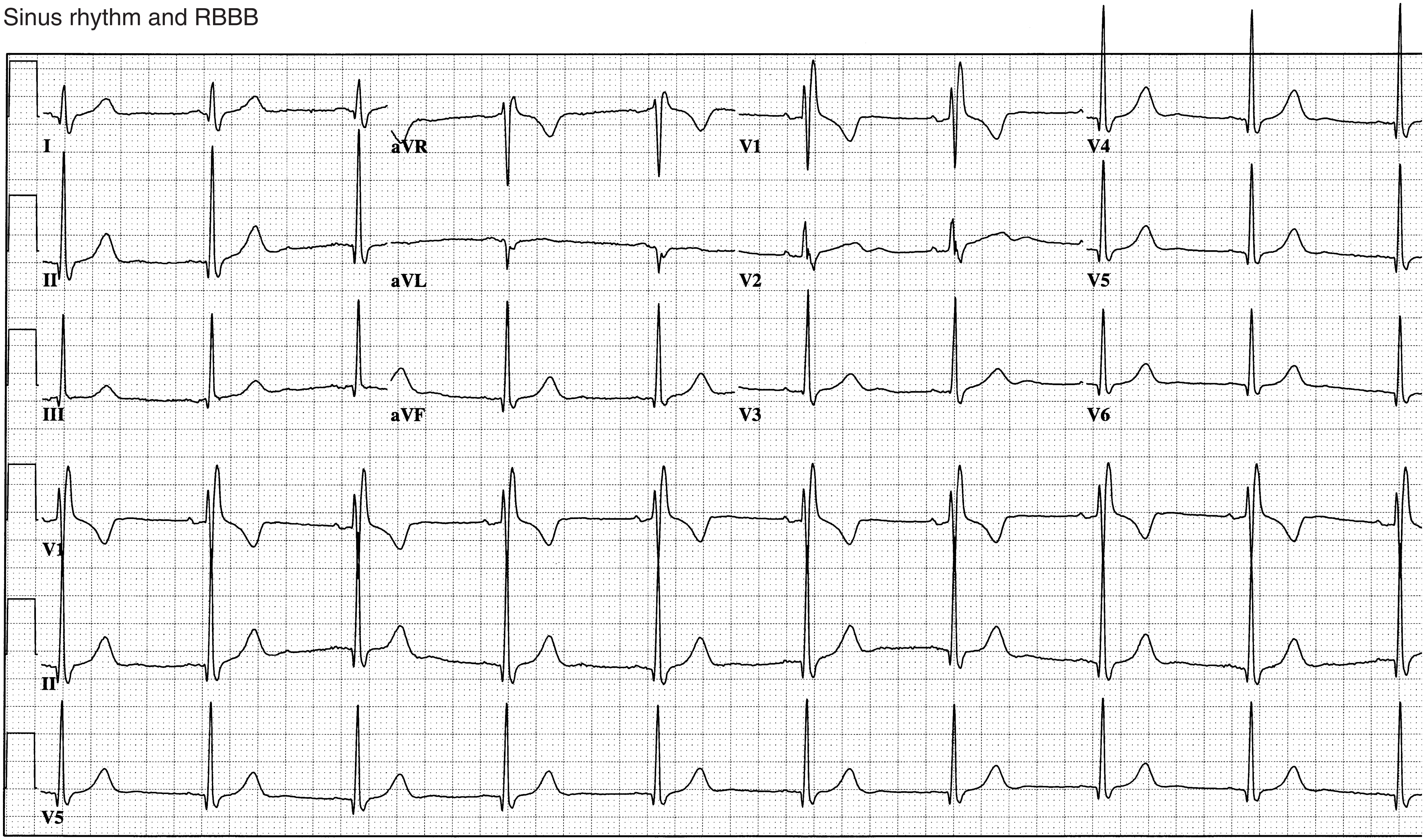
DAY 9-17

Sinus bradycardia with an acute inferior-posterior MI. Note the ST segment elevation in the inferior leads, the ST segment depression in V_1 and V_2 and the tall R wave in V_2.



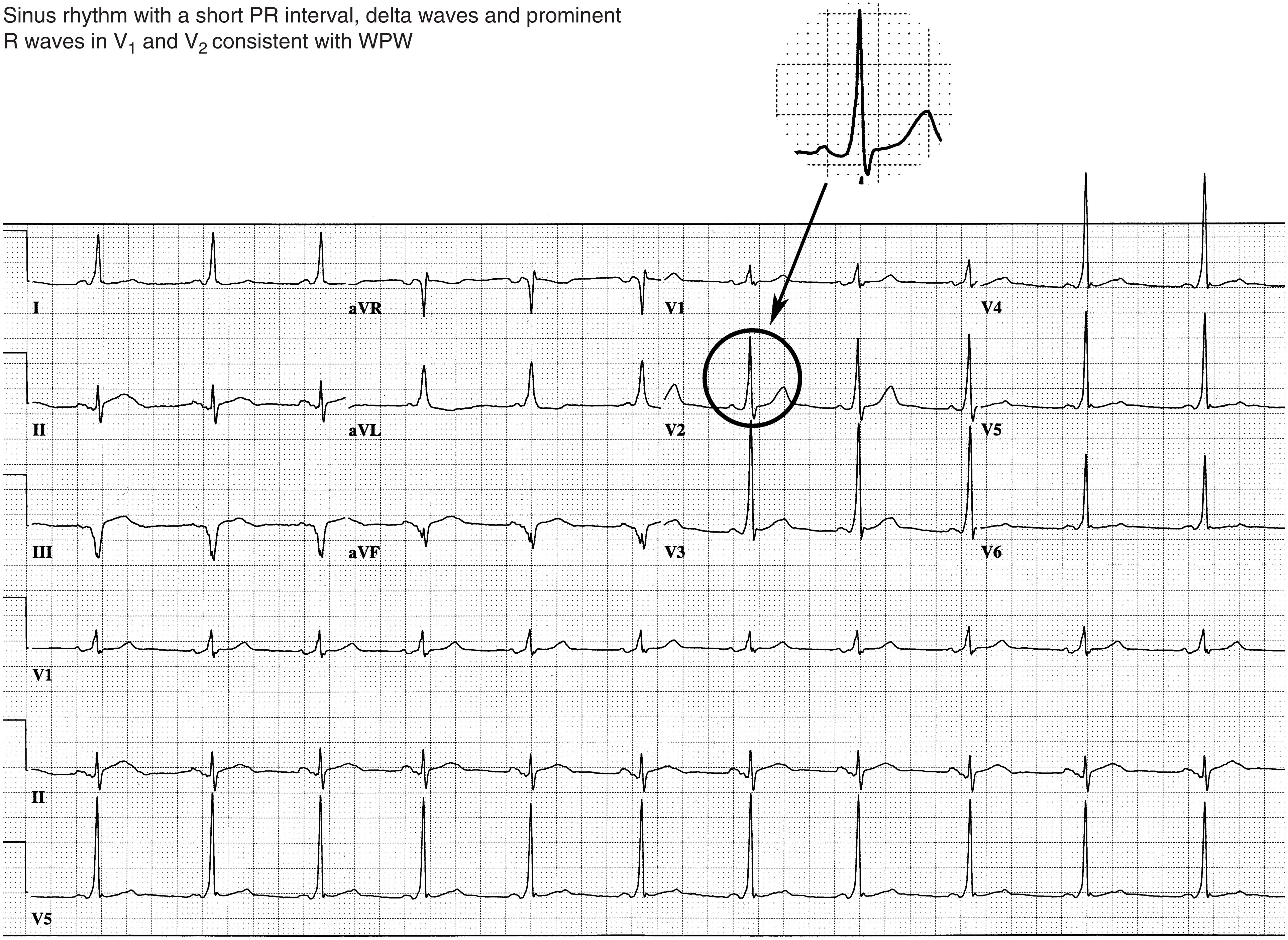
DAY 9-18

Sinus rhythm and RBBB



DAY 9-19

Sinus rhythm with a short PR interval, delta waves and prominent R waves in V_1 and V_2 consistent with WPW

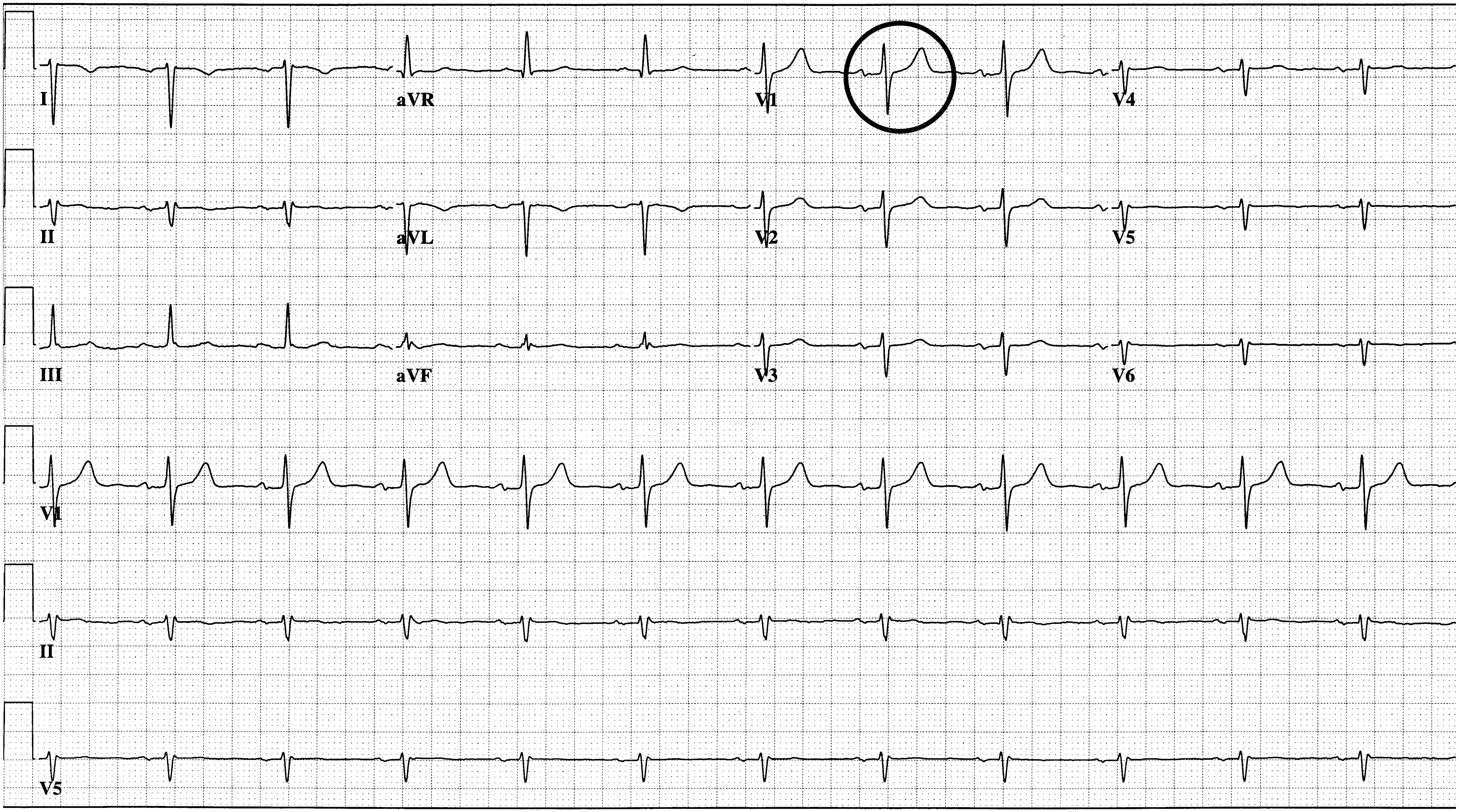


DAY 9-20

Sinus rhythm with very prominent R waves in V_1 and particularly V_2 in a patient with hypertrophic cardiomyopathy and an extremly thickened septum

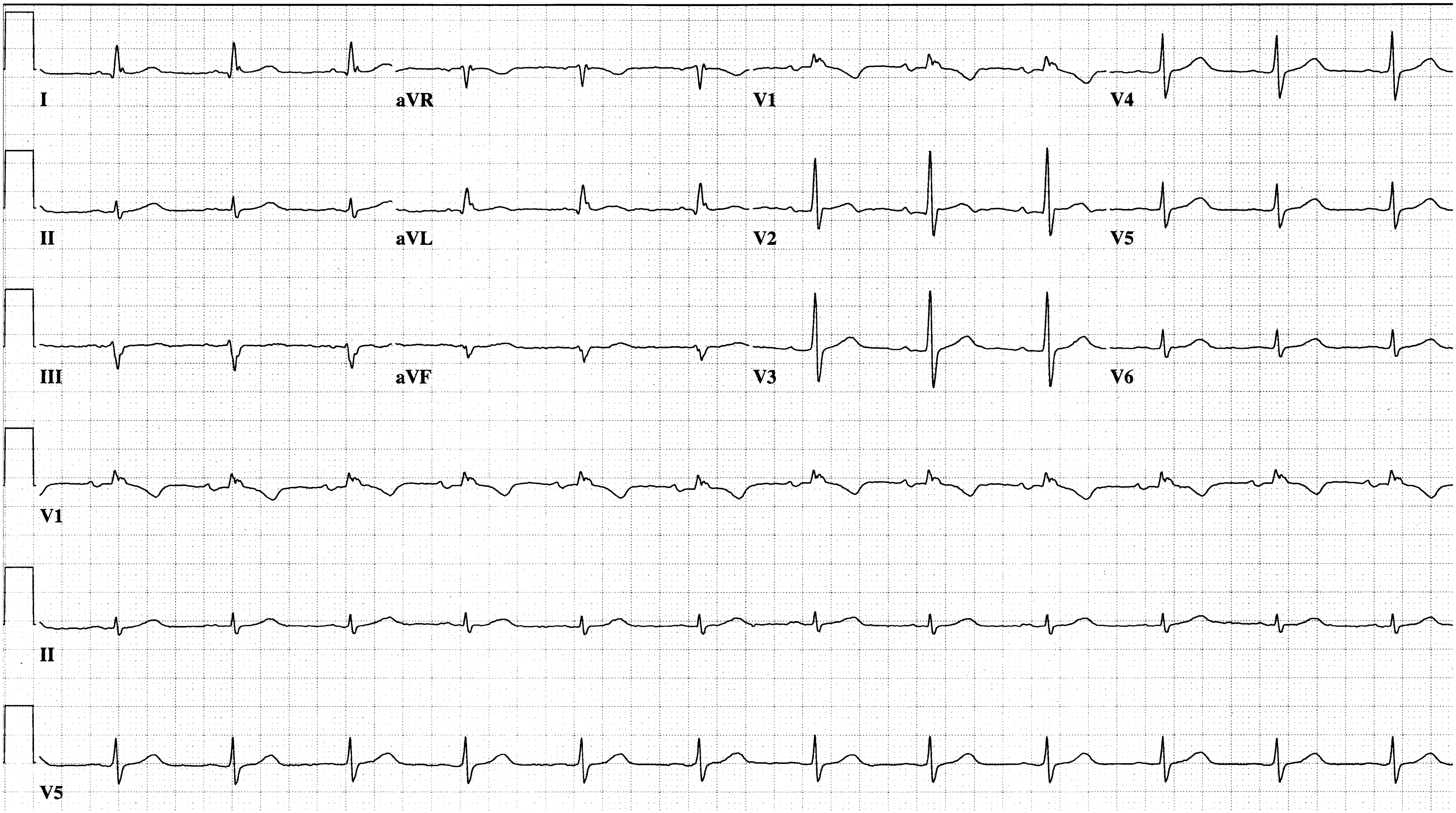
DAY 9-21

An abnormal P wave and QRS axis, a tall R wave in V_1, and decresing R waves across the remaining precordial leads in theis patient with *situs inversis dextrocardia*



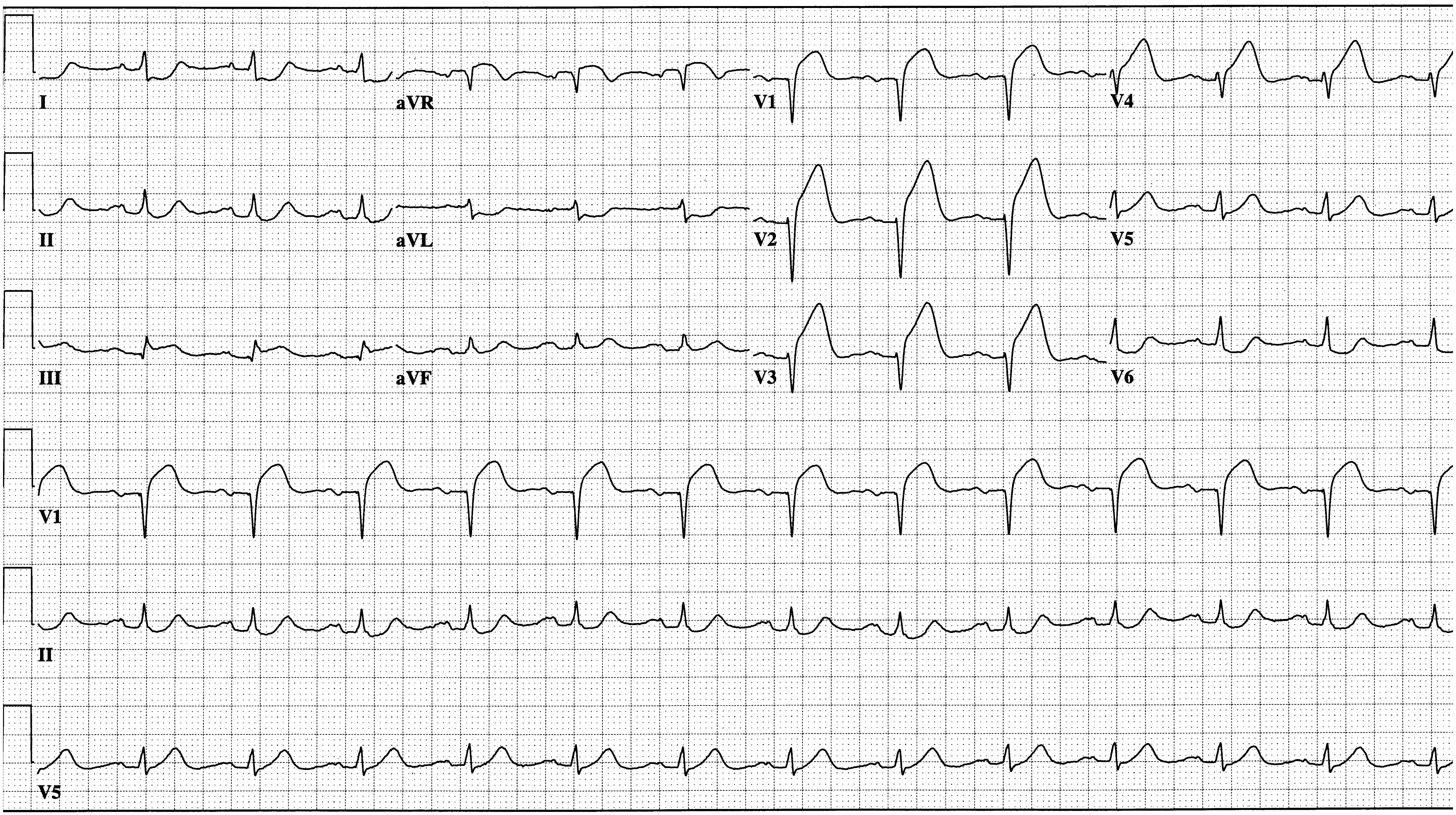
DAY 9-22

Sinus rhythm with a prominent R wave in V_1 and V_2 in a boy with Duchenne's muscular dystrophy



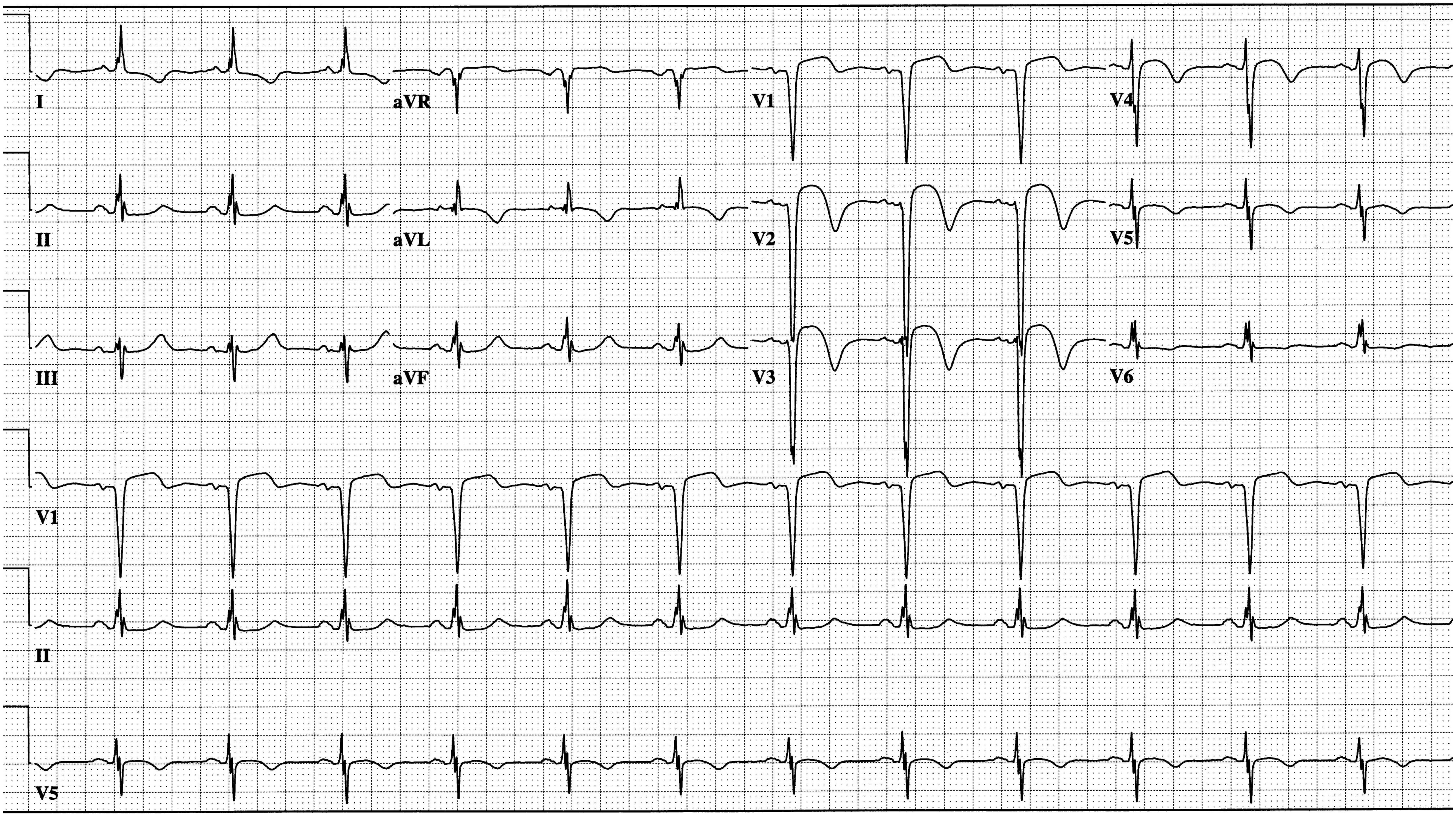
DAY 9-23

Sinus rhythm with an acute anteroseptal MI



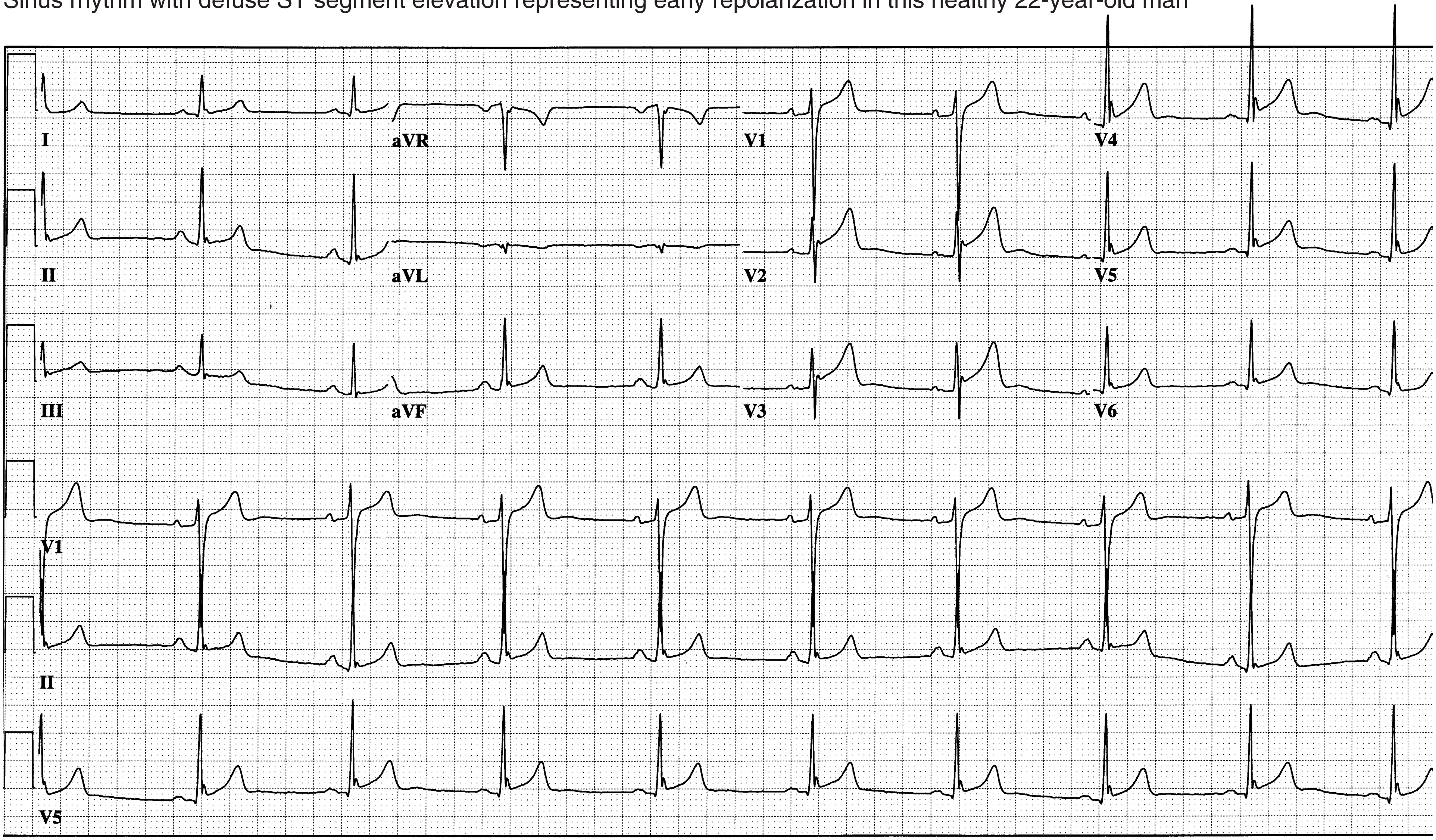
DAY 9-24

Sinus rhythm with Q waves, ST segment elevation, and T wave inversion in V_1-V_3, all consistent with an anteroseptal MI. However, these findings were present on a previous ECG from 6 months previously, strongly suggesting that the residual ST segment elevation represents a left ventricular aneurysm.



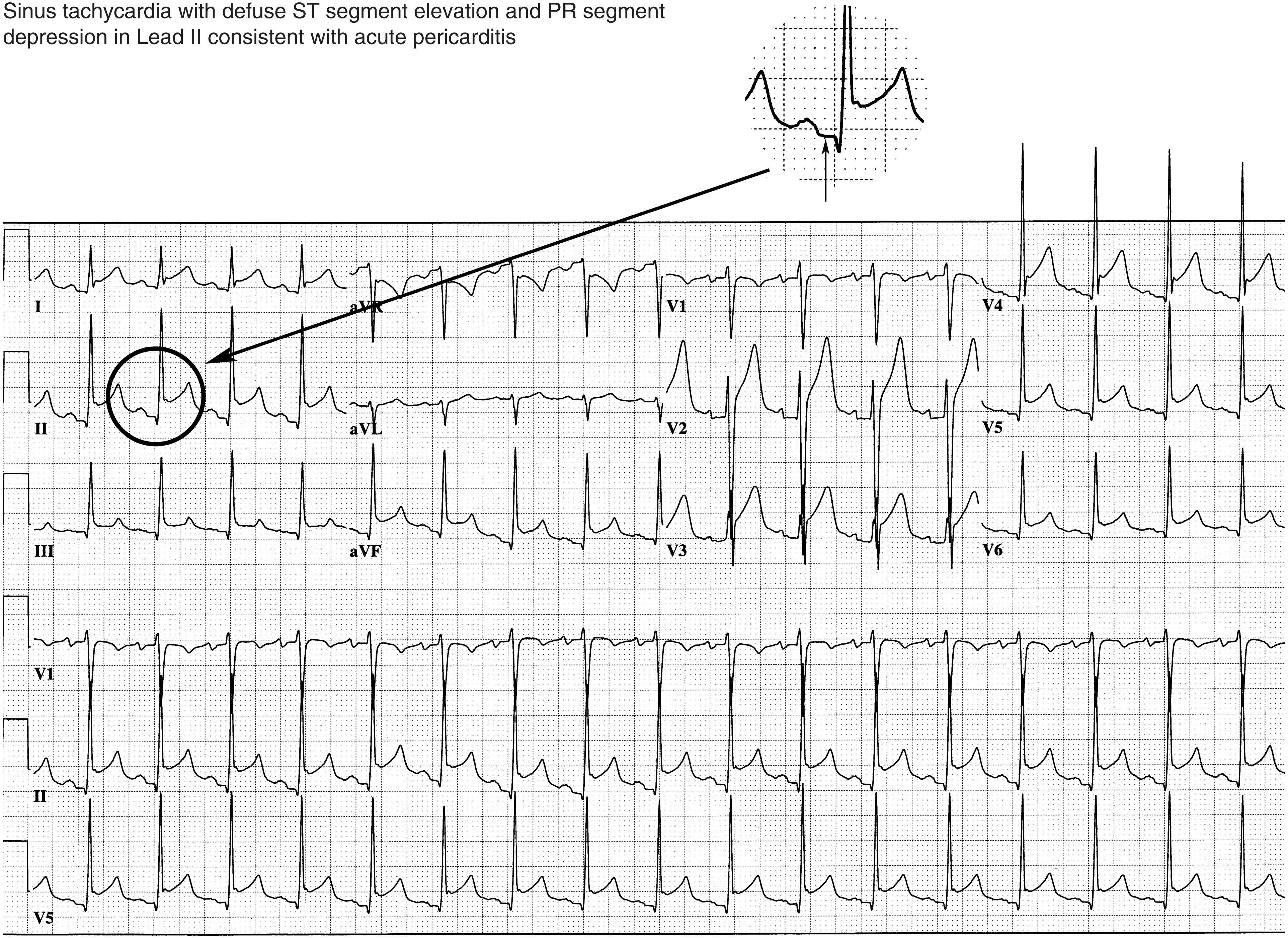
DAY 9-25

Sinus rhythm with defuse ST segment elevation representing early repolarization in this healthy 22-year-old man



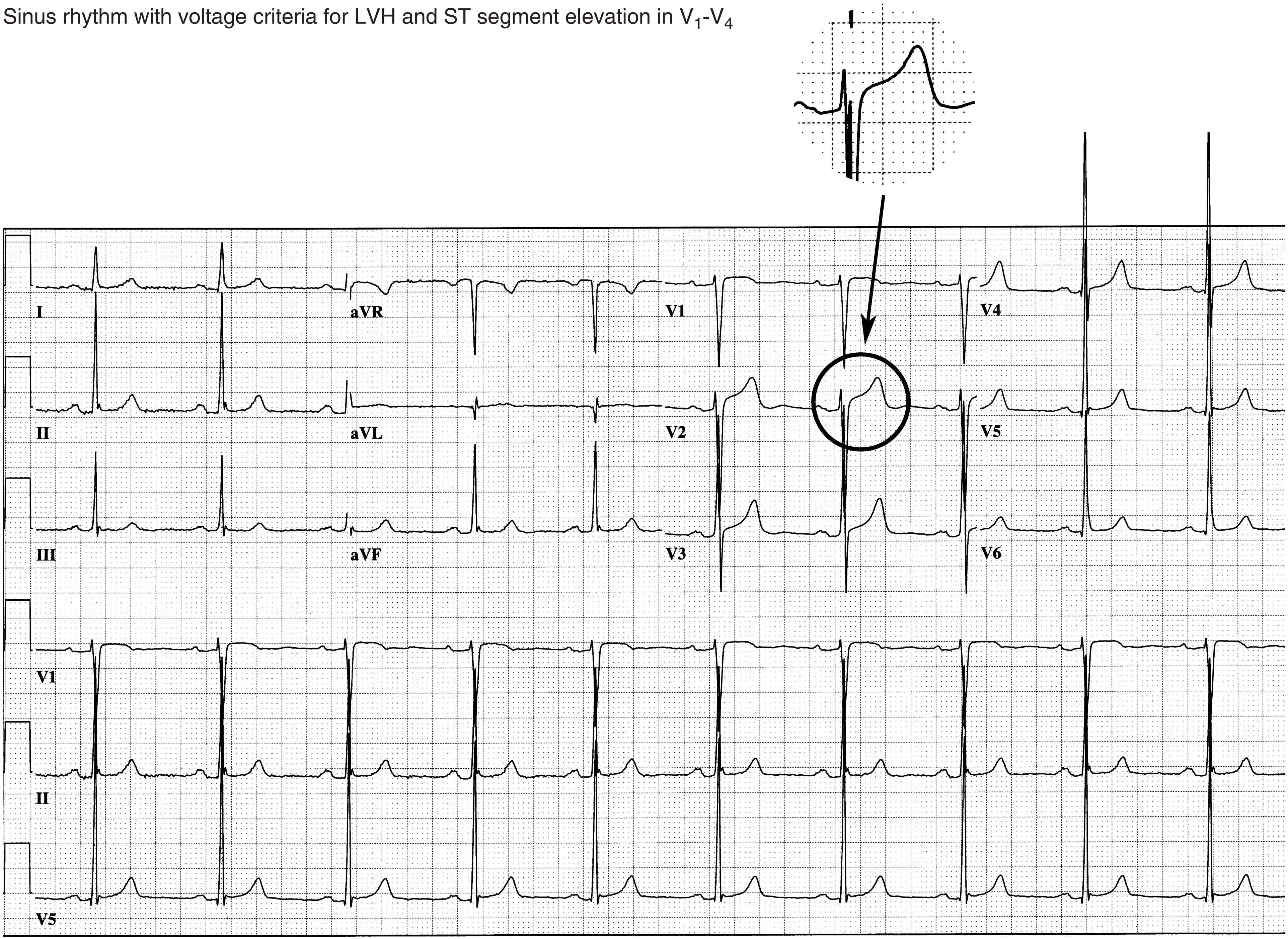
DAY 9-26

Sinus tachycardia with defuse ST segment elevation and PR segment depression in Lead II consistent with acute pericarditis



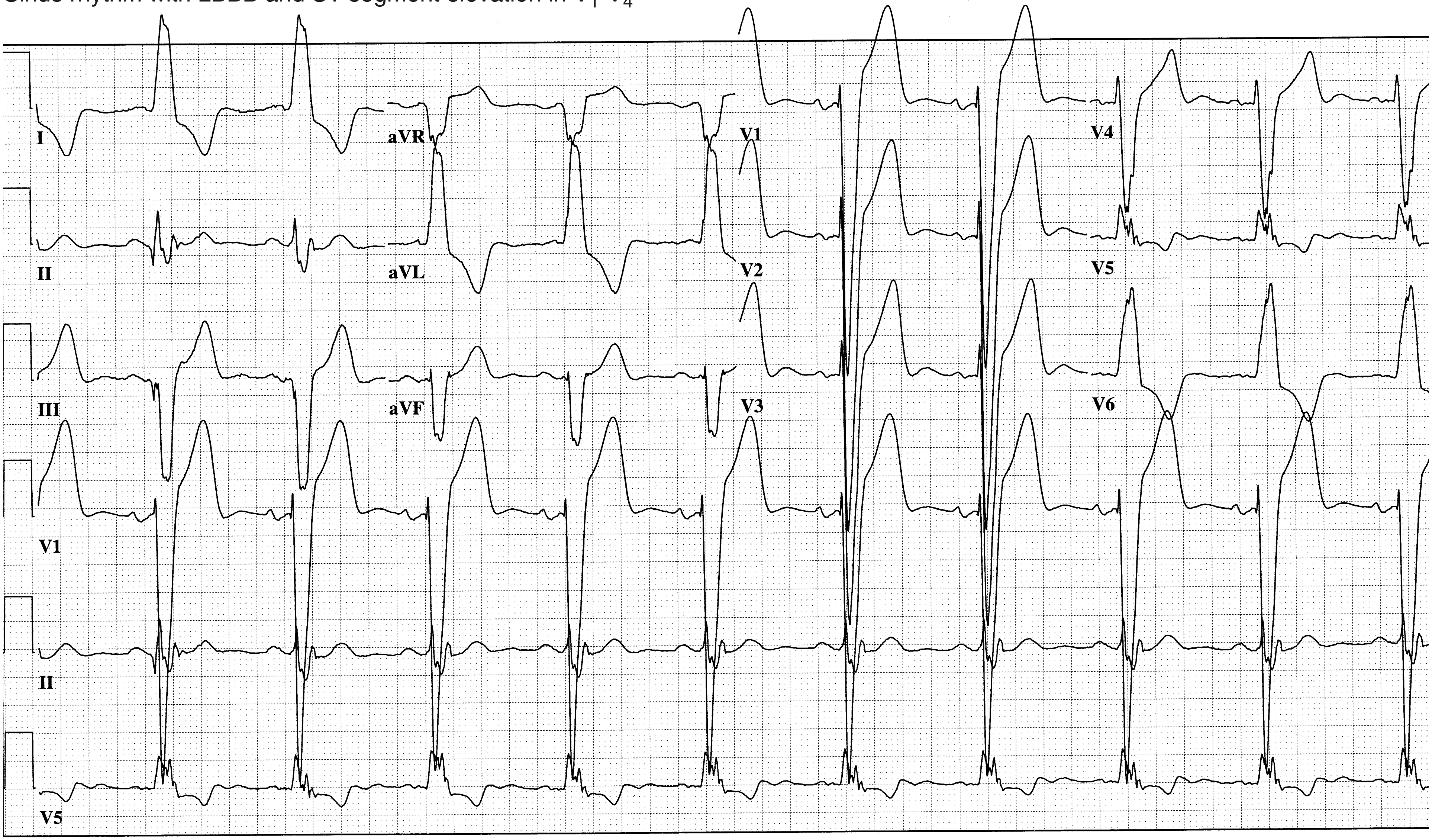
DAY 9-27

Sinus rhythm with voltage criteria for LVH and ST segment elevation in V_1-V_4



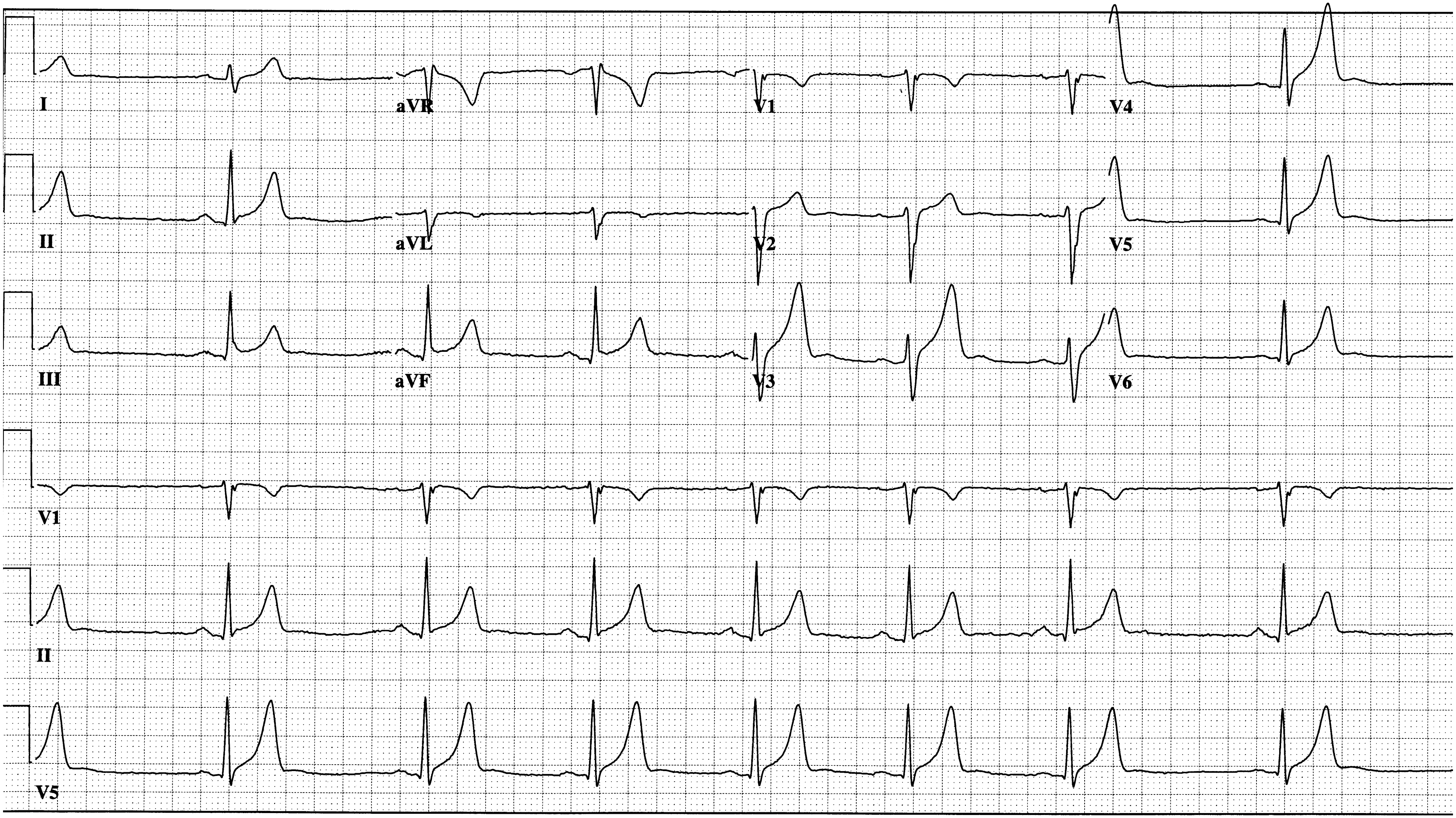
DAY 9-28

Sinus rhythm with LBBB and ST segment elevation in V_1-V_4



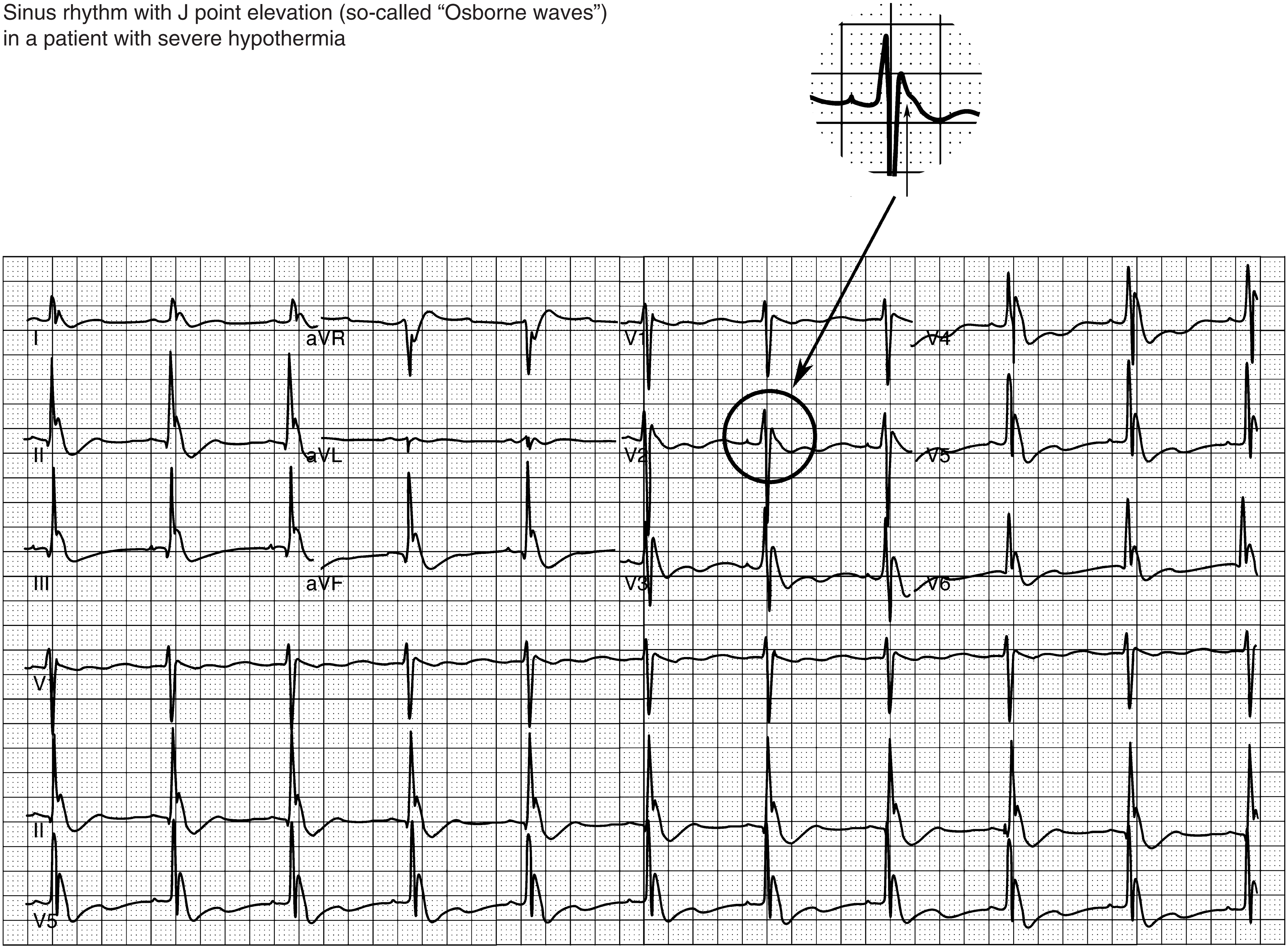
DAY 9-29

Sinus bradycardia with ST segment elevation and peaked T waves in a patient with early hyperkalemia (K = 6.3 mmol/l)



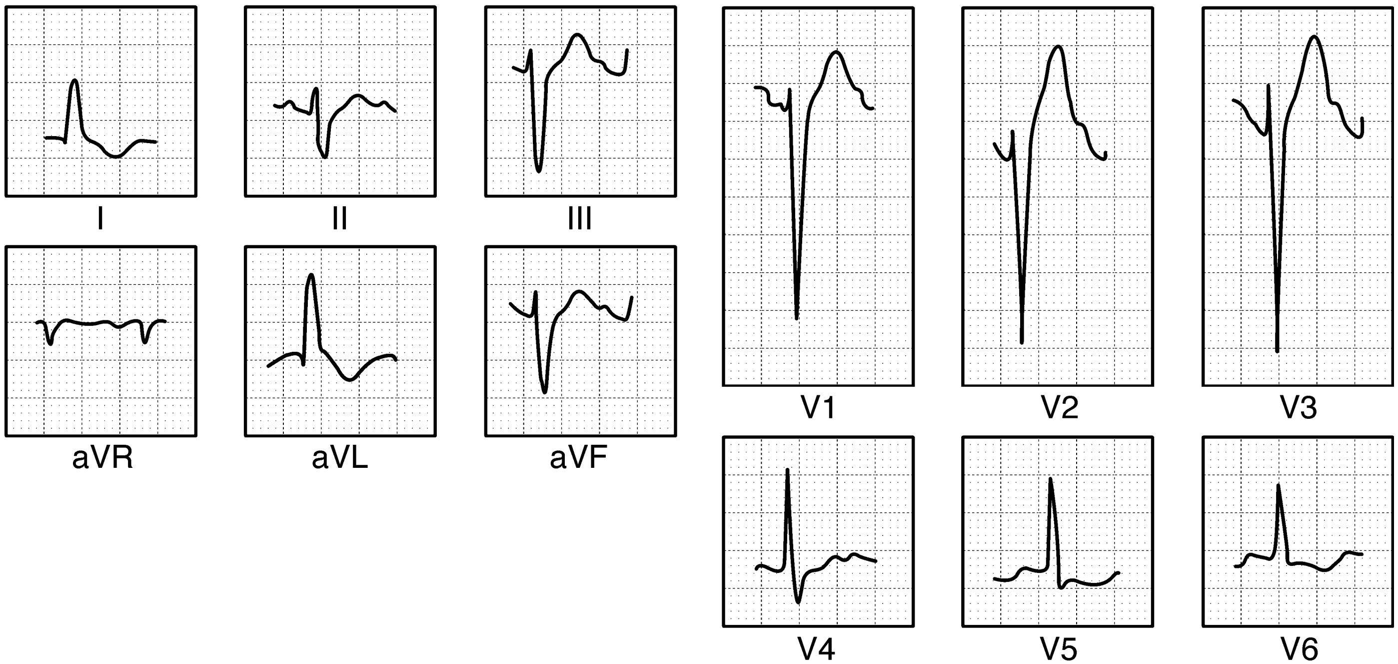
DAY 9-30

Sinus rhythm with J point elevation (so-called “Osborne waves”)
in a patient with severe hypothermia



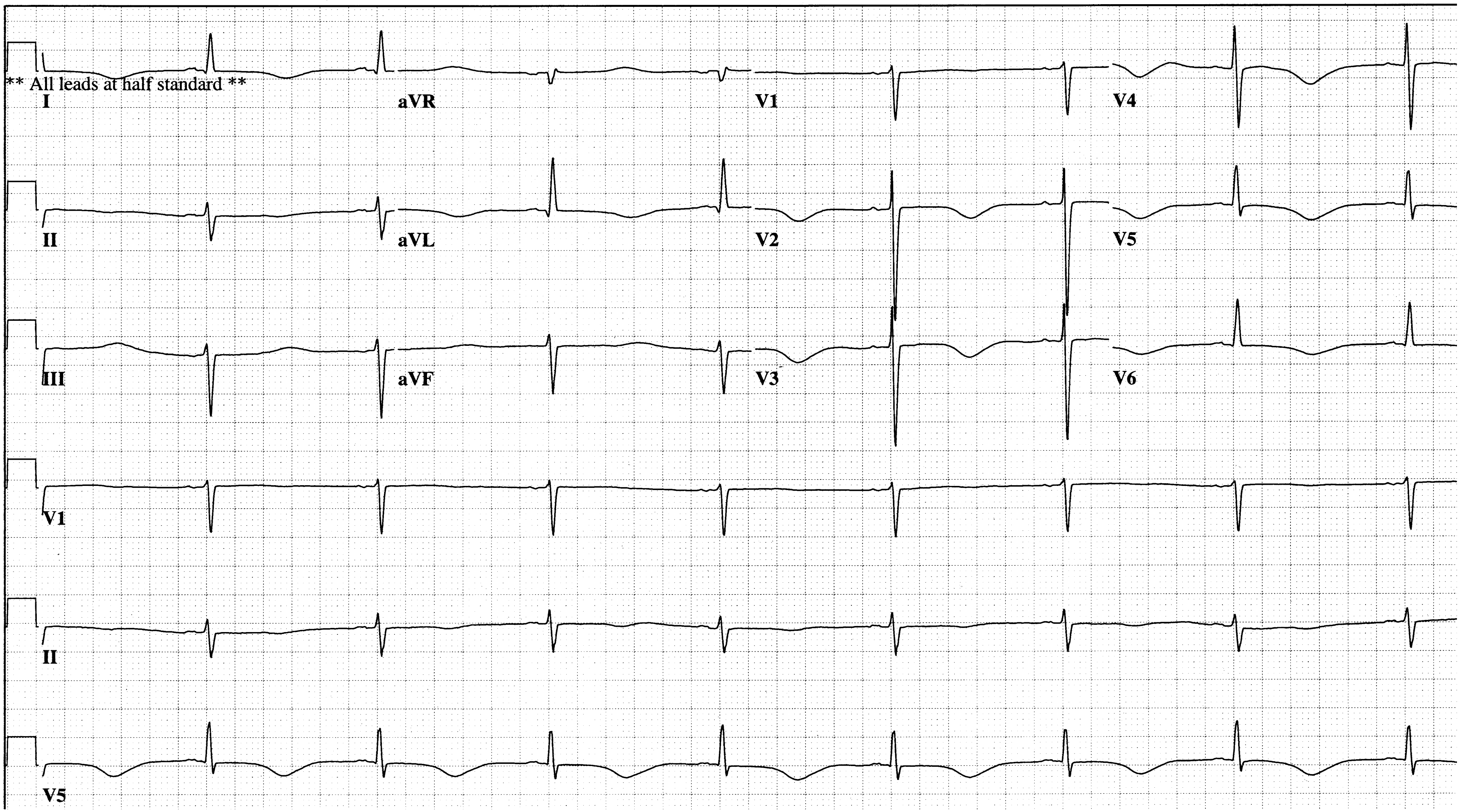
DAY 9-31

Diffuse ST segment changes in a child stung by an Indian red scorpion [from Bawaskar HS and Bawaskar PH, Management of the cardiovascular manifestations of poisoning by the Indian red scorpion (*Mesobuthus tamulus*). Br Heart J 1992;68:478–480]



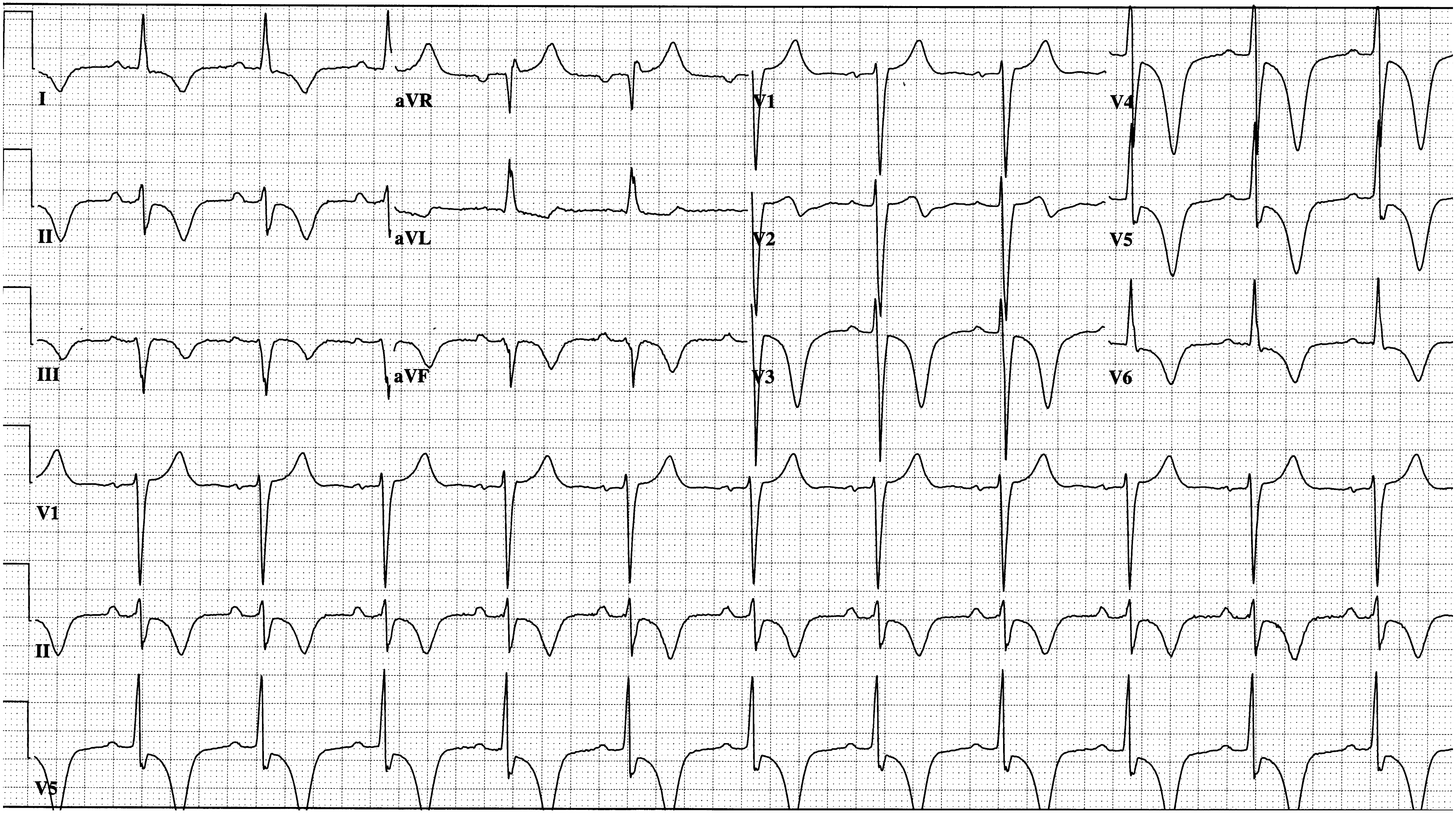
DAY 9-32

Sinus bradycardia, inverted T waves, and QT prolongation in a patient with meningitis and encephalitis



DAY 9-33

Sinus rhythm with LVH and deeply inverted T waves. An echocardiogram showed LVH and normal LV systolic function. A CT scan of the head showed an acute subarachnoid hemorrhage.



Sample Tracings
ECG 1

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

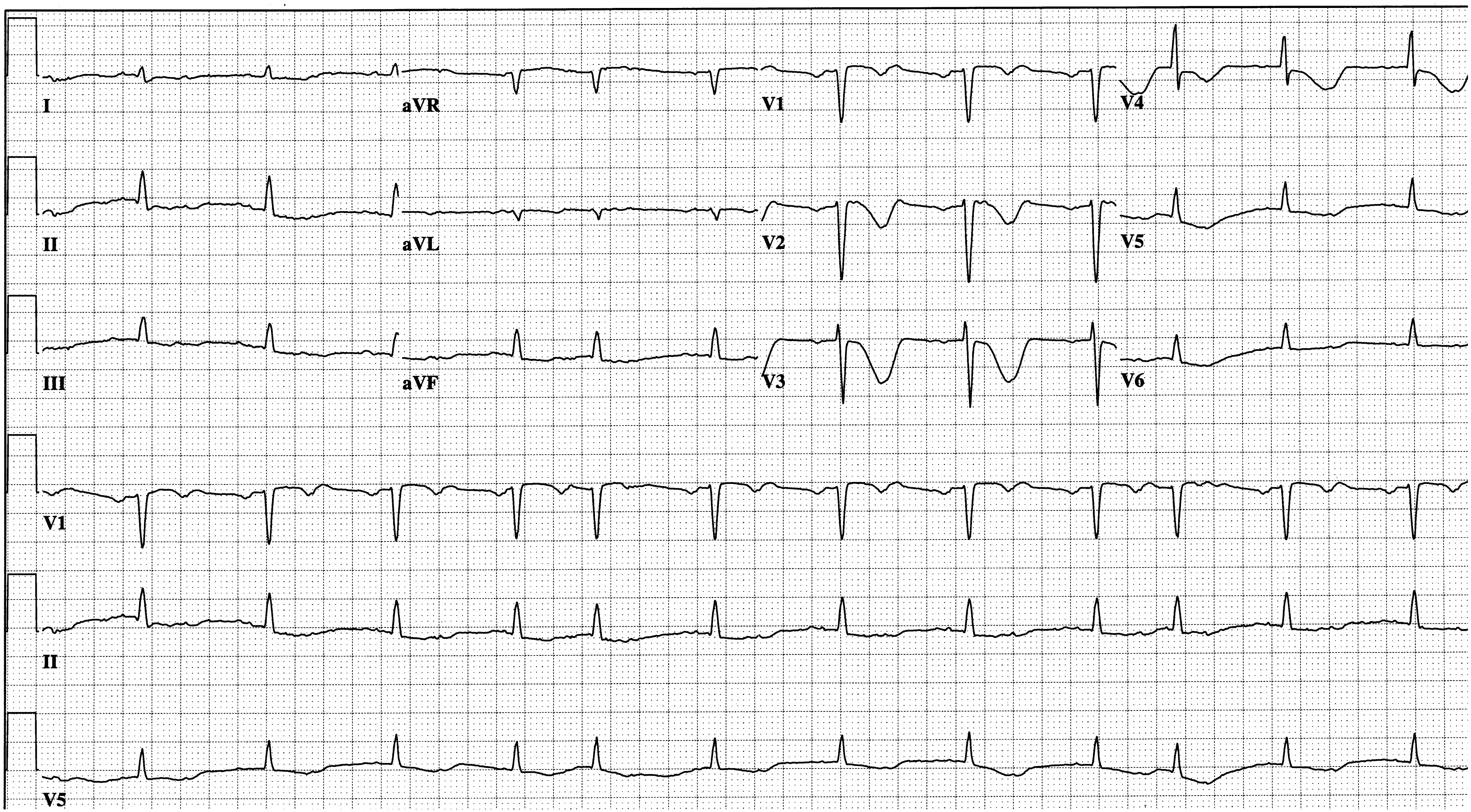
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG 2

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

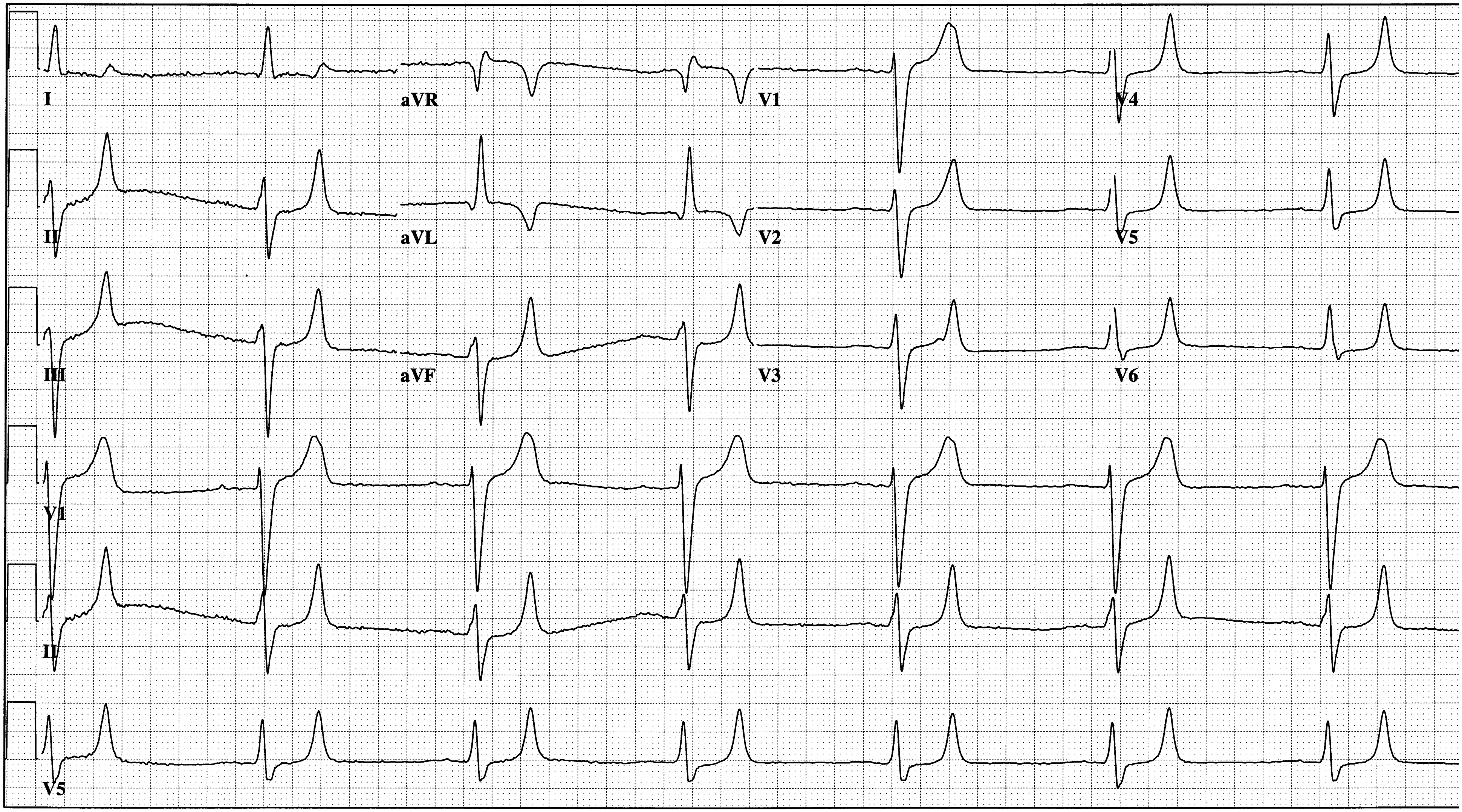
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 3

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

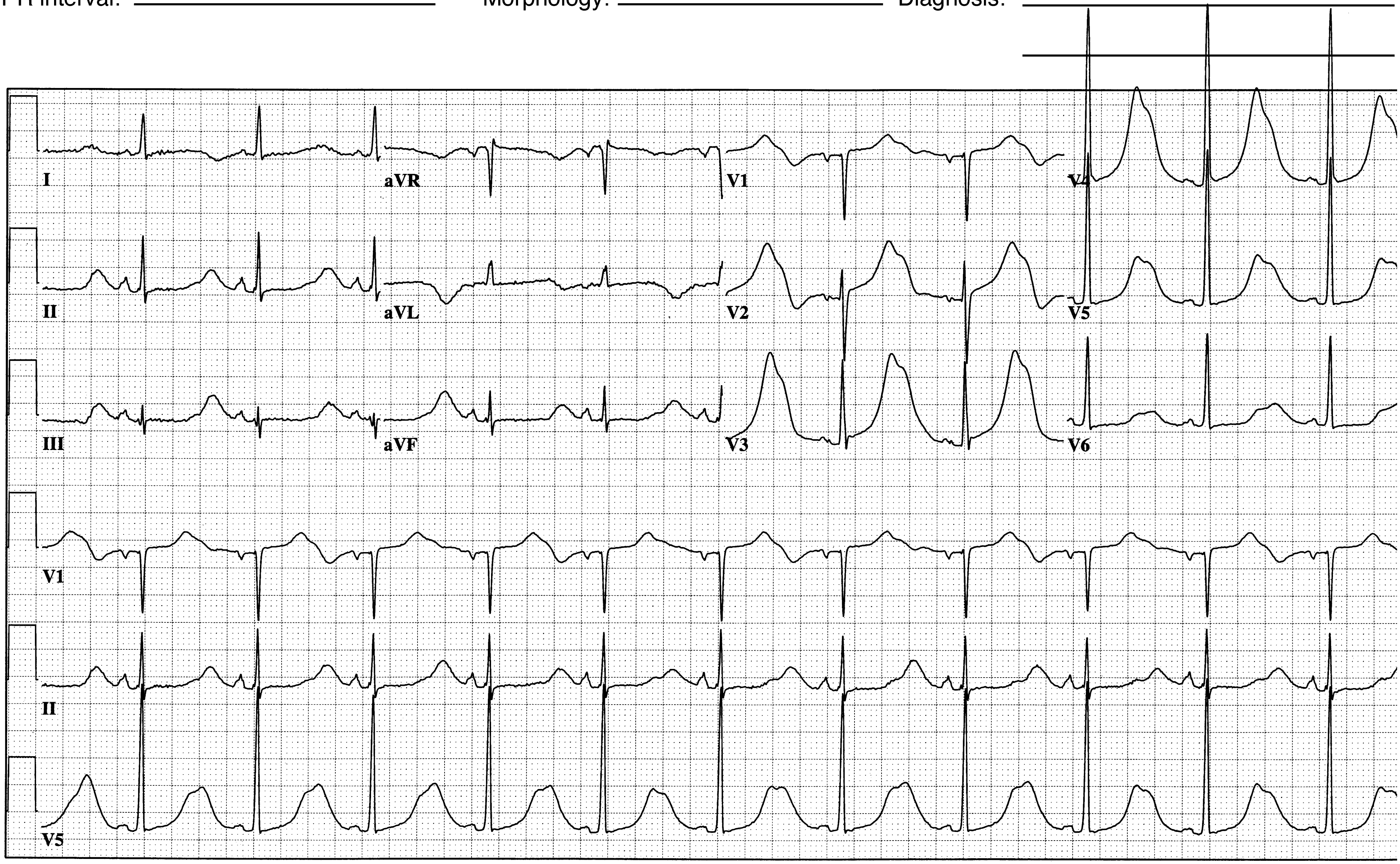
ST segment: ______

T wave: ______

QT interval: ______

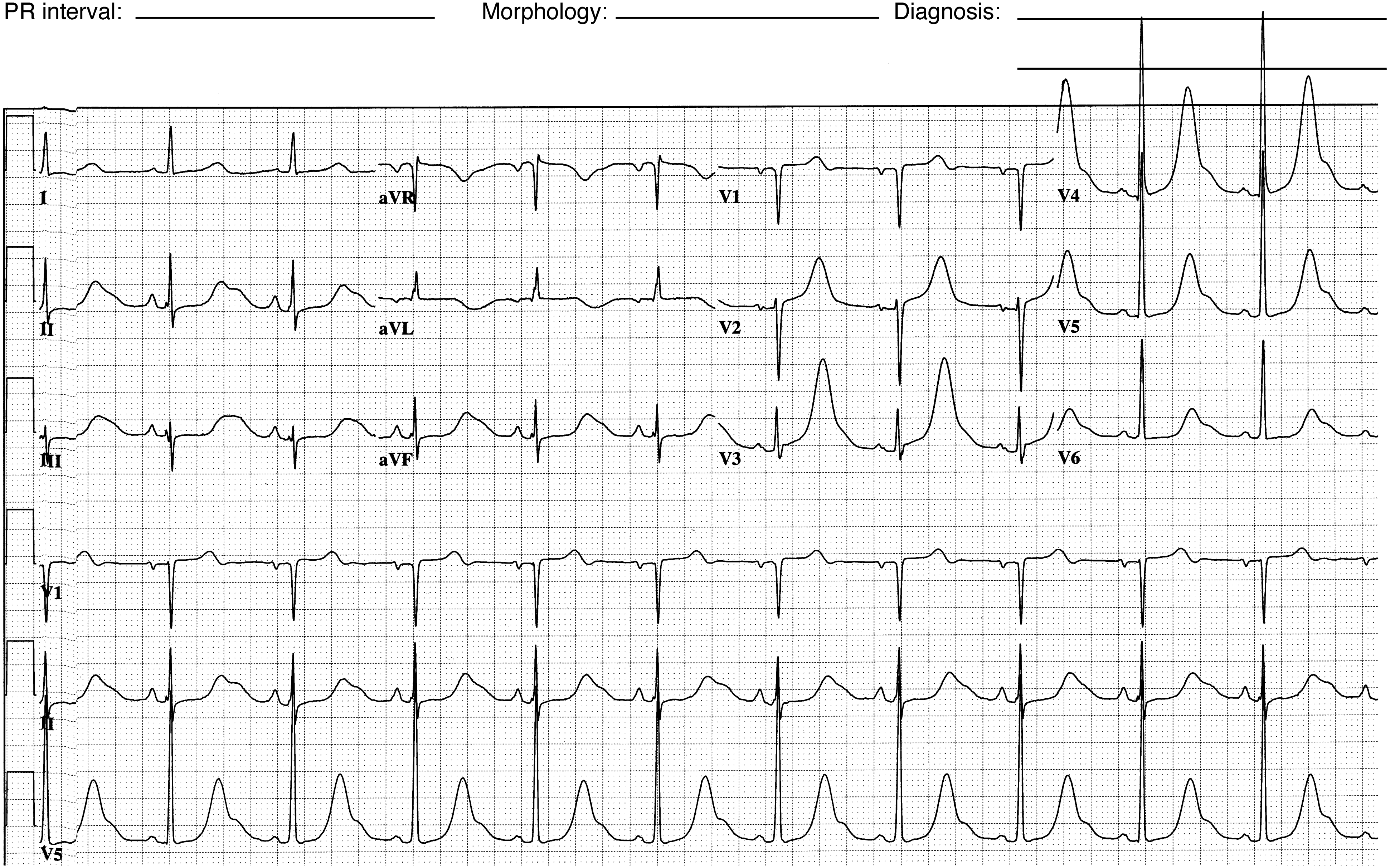
U wave: ______

Diagnosis: ______



ECG 4

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG 5

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

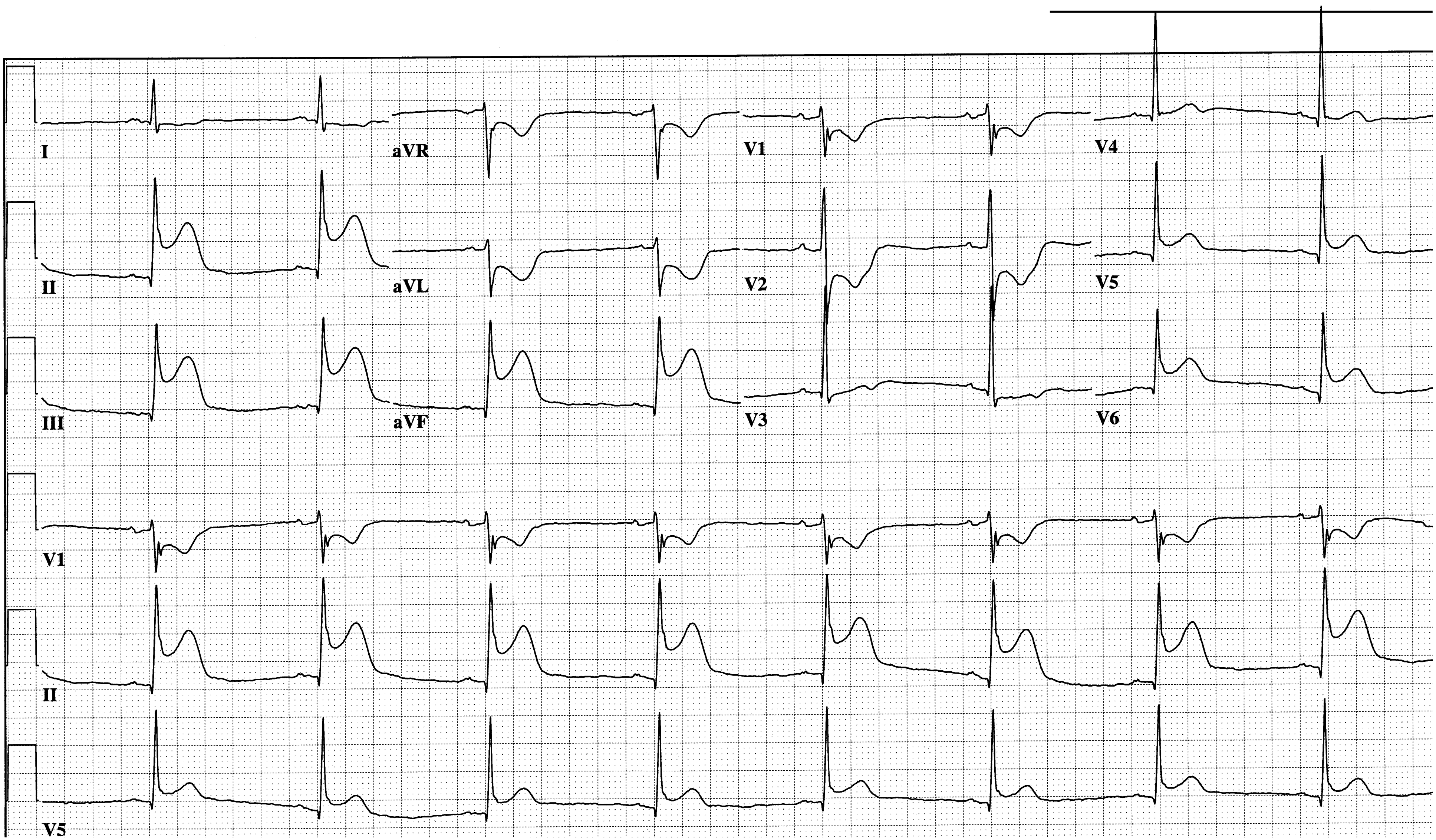
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 6

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______

ECG 7

Atrial rate: ______________

Ventricular rate: ______________

Rhythm: ______________

P wave: ______________

PR interval: ______________

QRS complex:

Axis: ______________

Duration: ______________

Voltage: ______________

Morphology: ______________

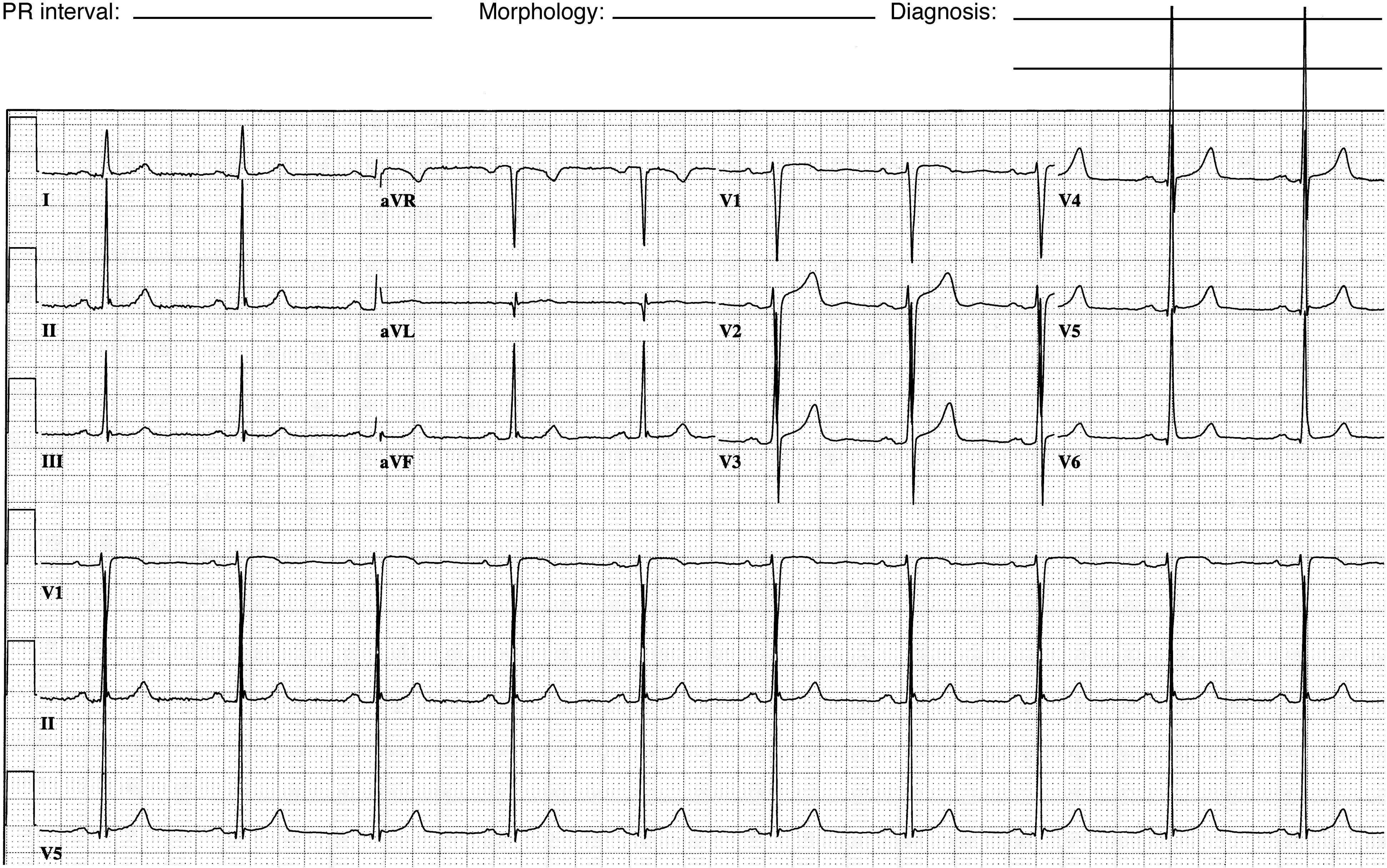
ST segment: ______________

T wave: ______________

QT interval: ______________

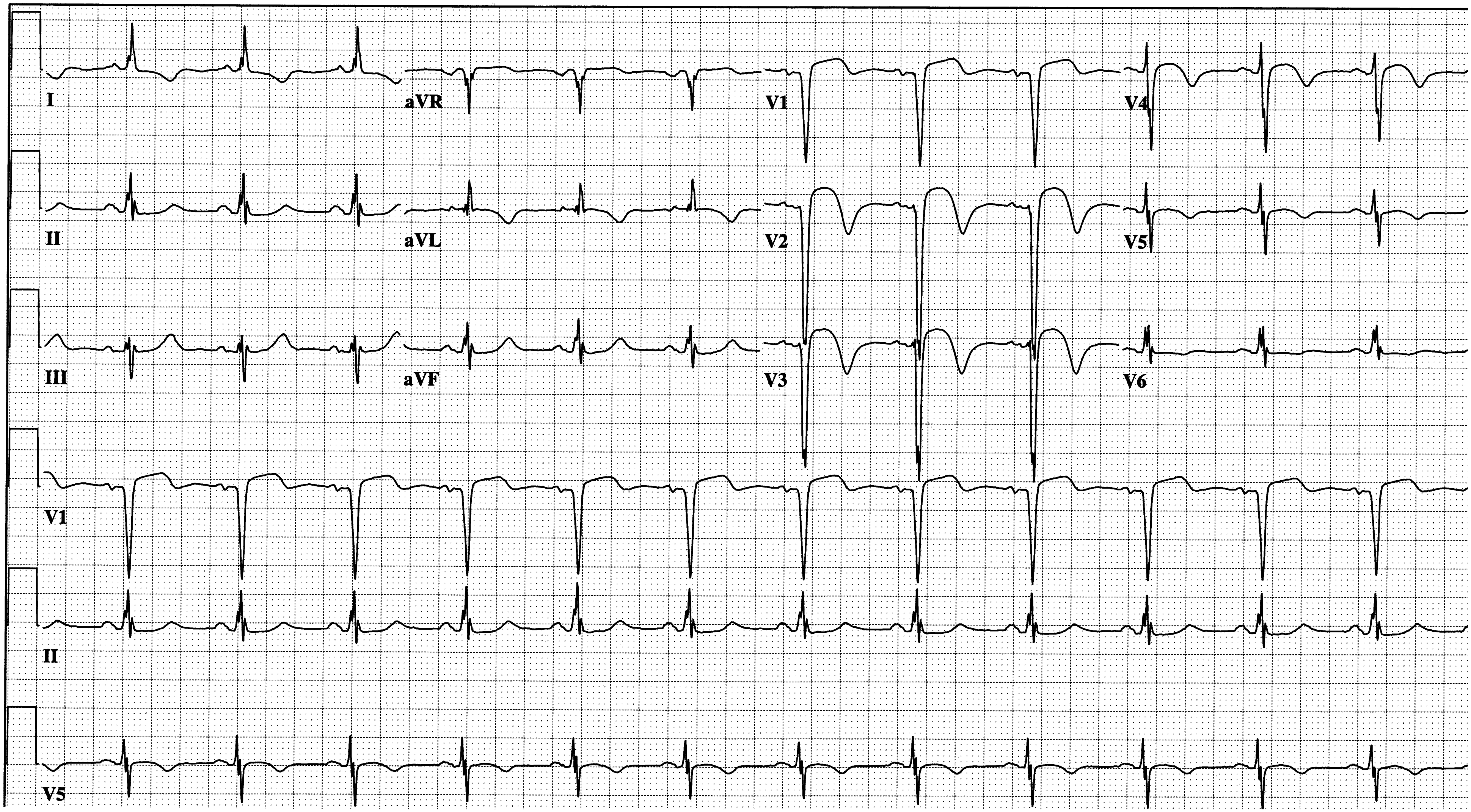
U wave: ______________

Diagnosis: ______________



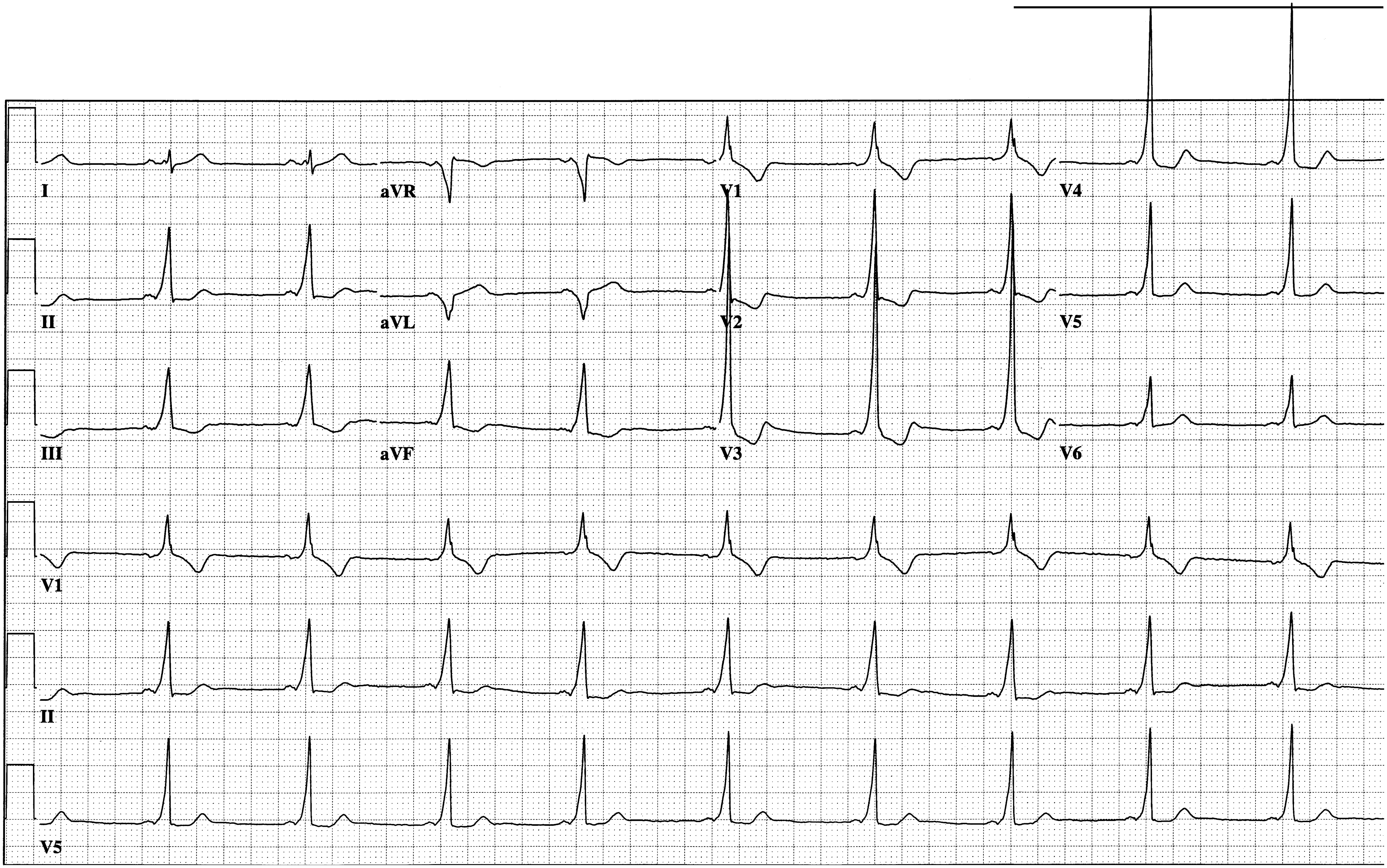
ECG 8

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



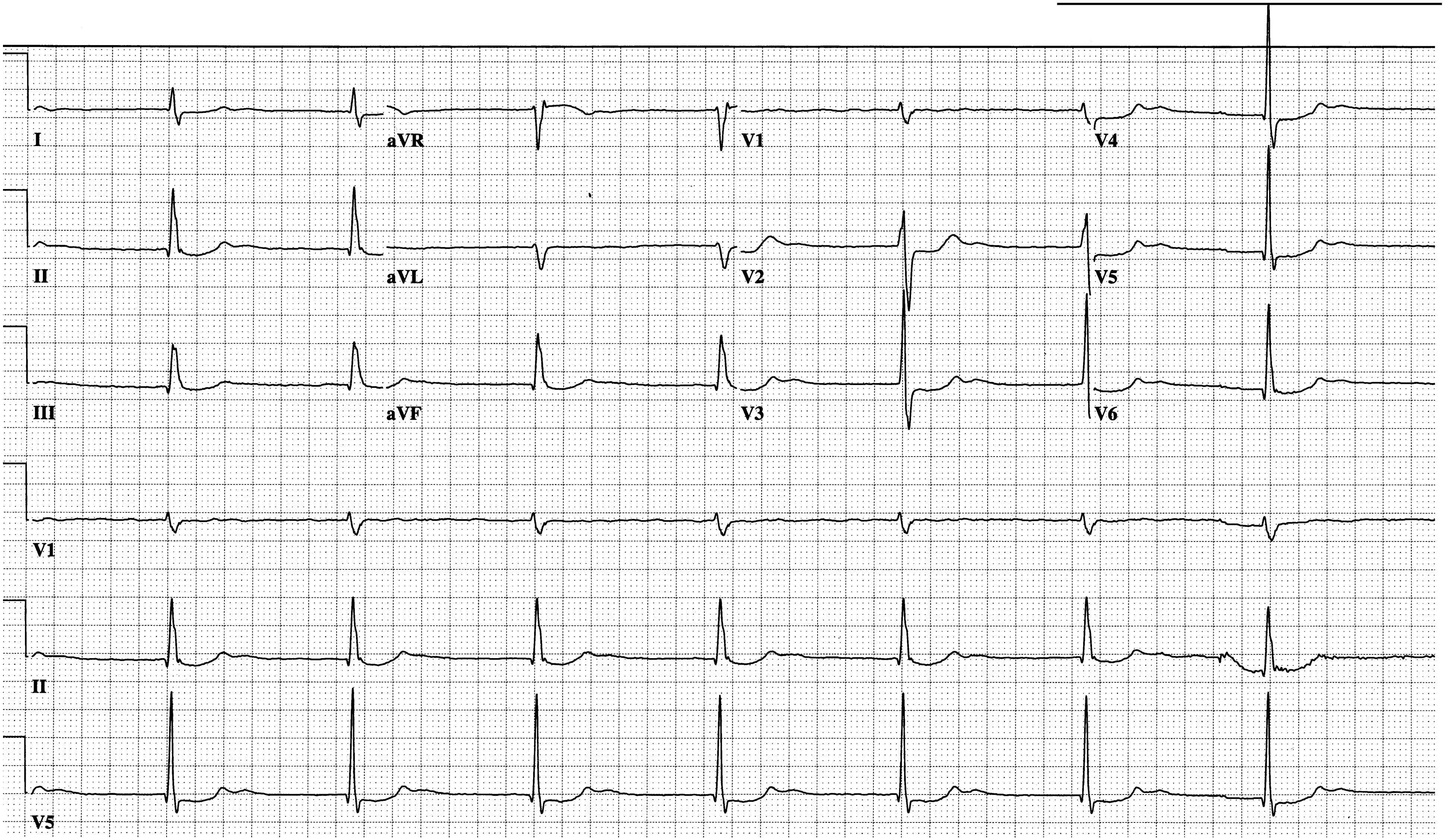
ECG 9

Ventricular rate: ________	Axis: ________	T wave: ________
Rhythm: ________	Duration: ________	QT interval: ________
P wave: ________	Voltage: ________	U wave: ________
PR interval: ________	Morphology: ________	Diagnosis: ________



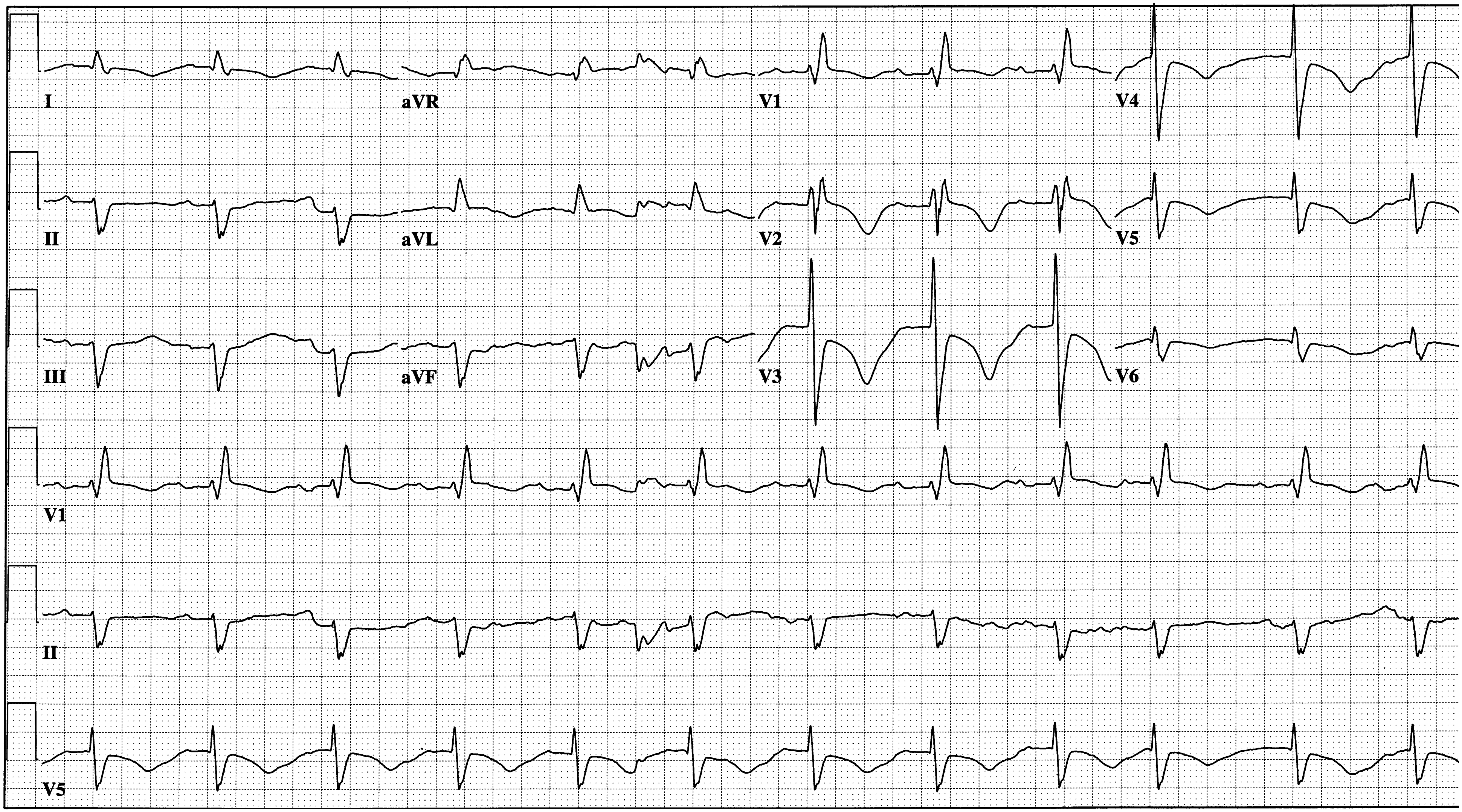
ECG 10

Atrial rate:	QRS complex:	ST segment:
Ventricular rate:	Axis:	T wave:
Rhythm:	Duration:	QT interval:
P wave:	Voltage:	U wave:
PR interval:	Morphology:	Diagnosis:



ECG 11

Atrial rate: ________	QRS complex:	ST segment: ________
Ventricular rate: ________	Axis: ________	T wave: ________
Rhythm: ________	Duration: ________	QT interval: ________
P wave: ________	Voltage: ________	U wave: ________
PR interval: ________	Morphology: ________	Diagnosis: ________



ECG 12

Atrial rate: ____________

Ventricular rate: ____________

Rhythm: ____________

P wave: ____________

PR interval: ____________

QRS complex:

Axis: ____________

Duration: ____________

Voltage: ____________

Morphology: ____________

ST segment: ____________

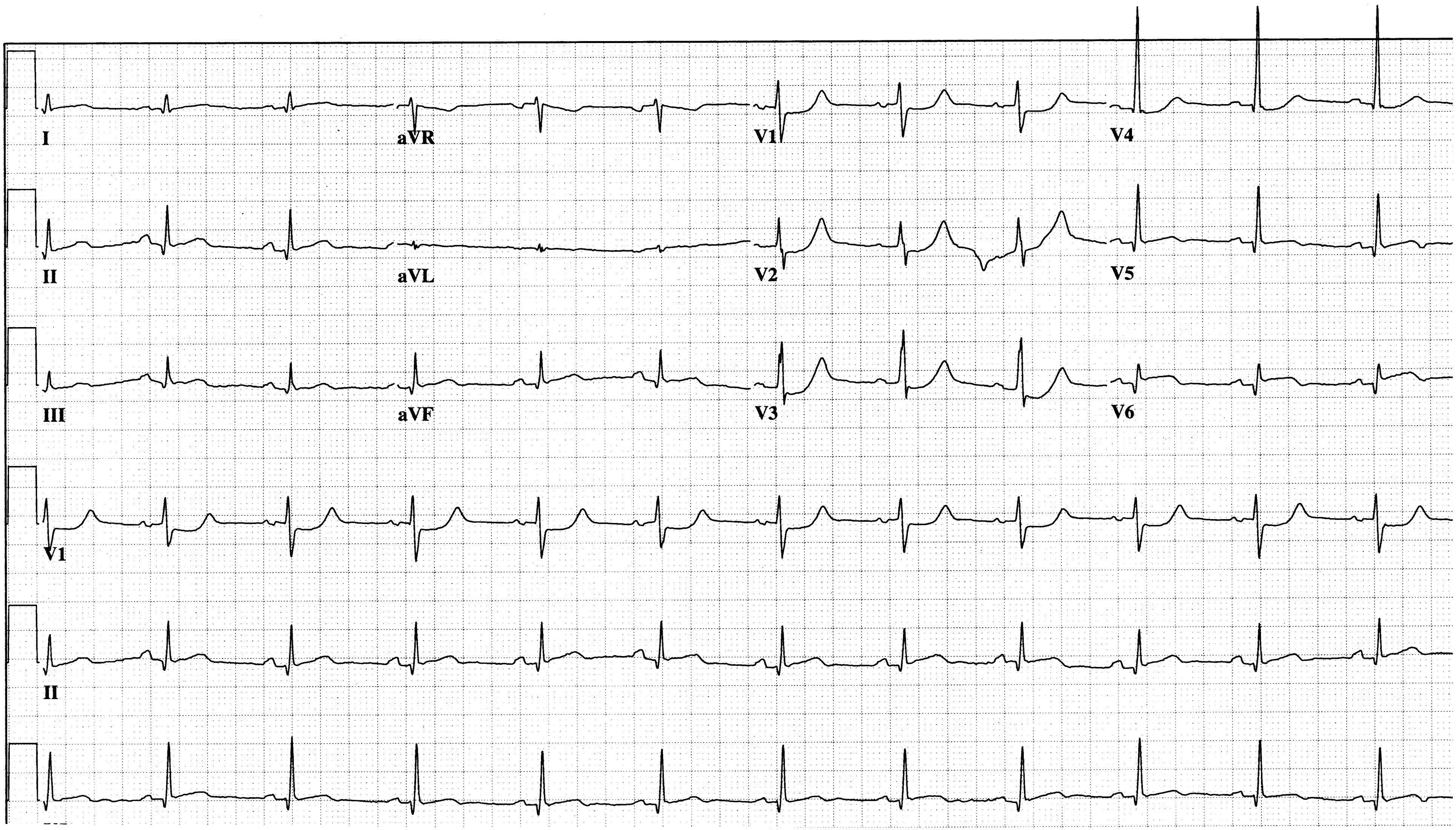
T wave: ____________

QT interval: ____________

U wave: ____________

Diagnosis: ____________

____



ECG 13

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

ST segment: ____________________

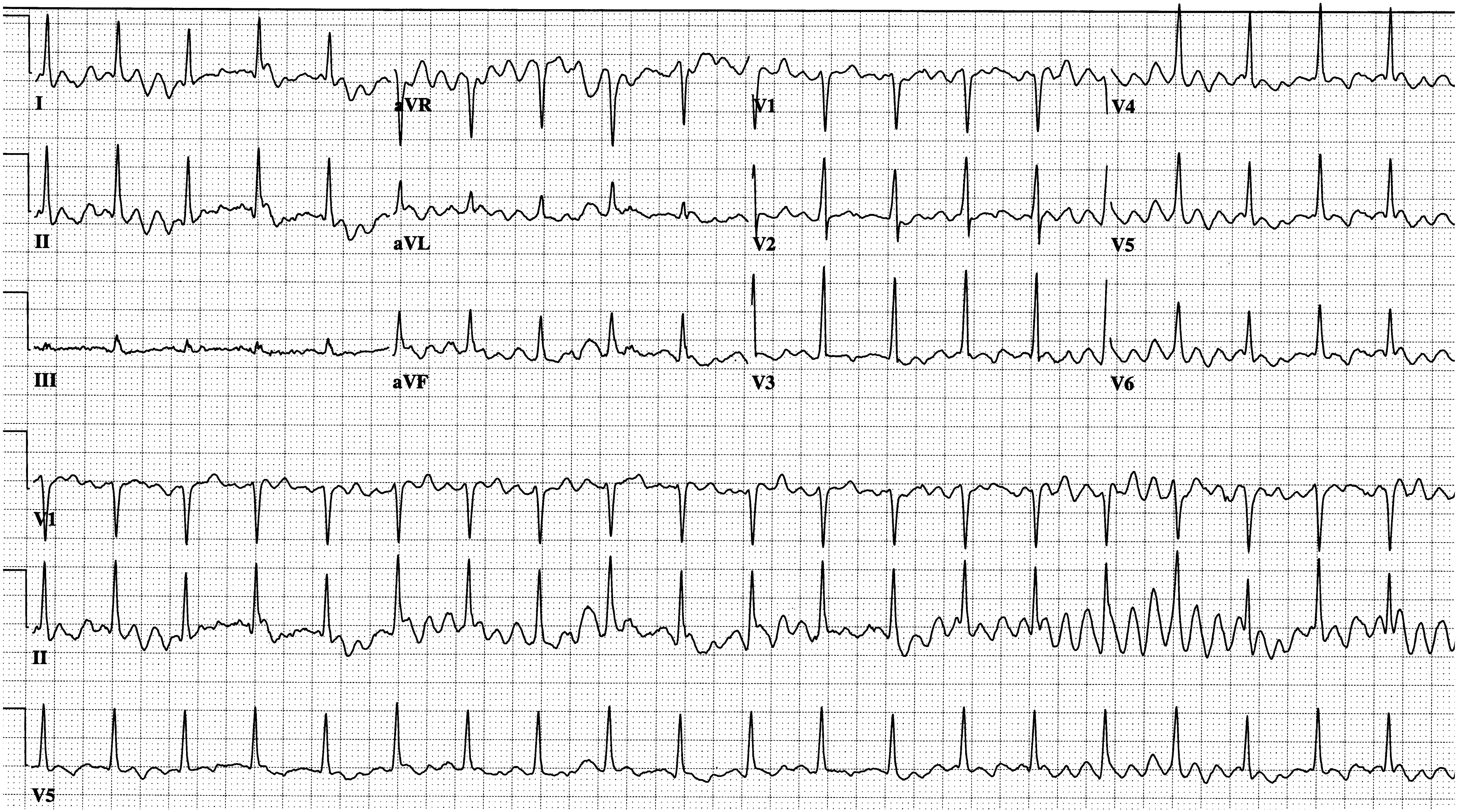
T wave: ____________________

QT interval: ____________________

U wave: ____________________

Diagnosis: ____________________

____



ECG 14

Atrial rate: __________

Ventricular rate: __________

Rhythm: __________

P wave: __________

PR interval: __________

QRS complex:

Axis: __________

Duration: __________

Voltage: __________

Morphology: __________

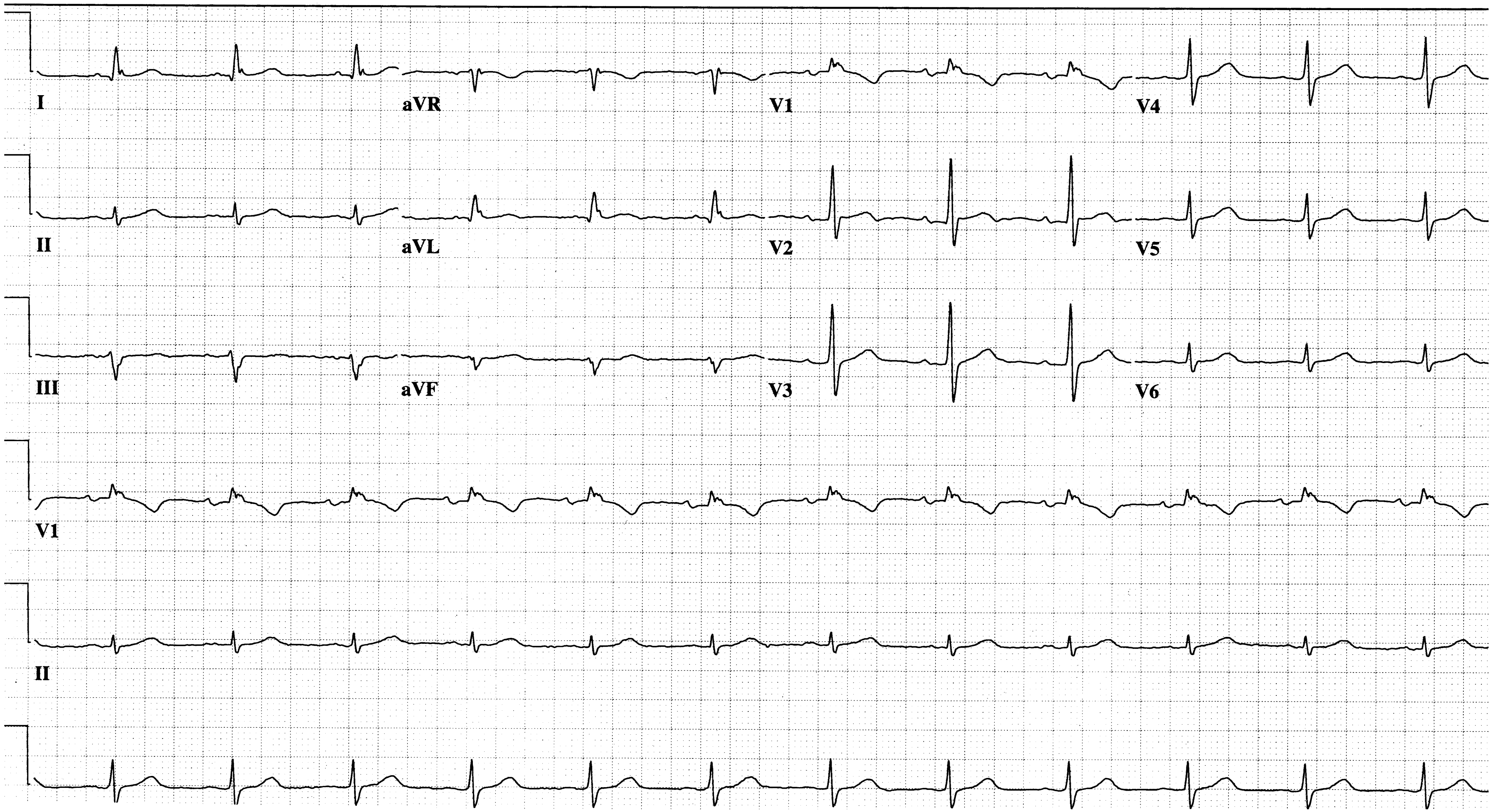
ST segment: __________

T wave: __________

QT interval: __________

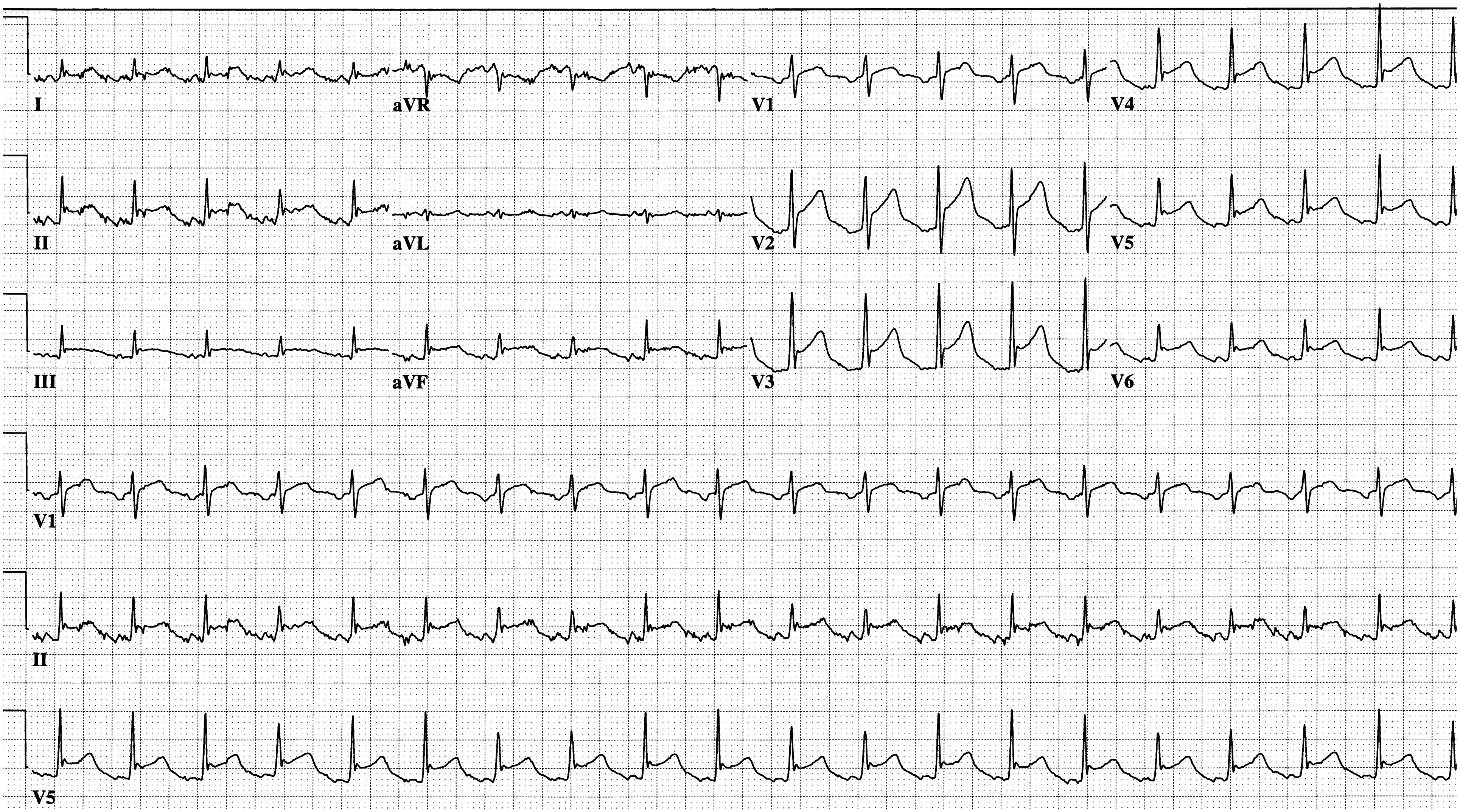
U wave: __________

Diagnosis: __________



ECG 15

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG 16

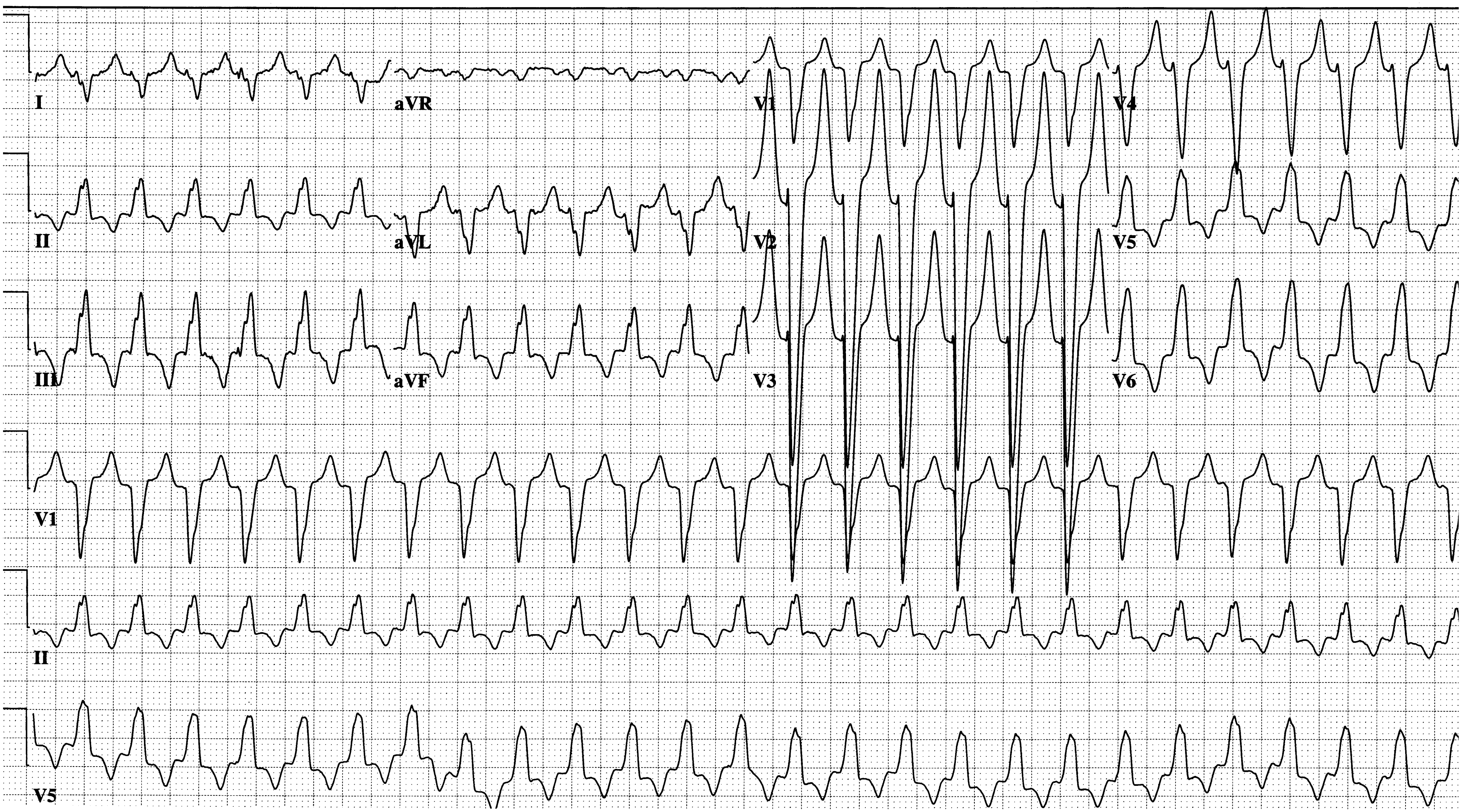
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG 17

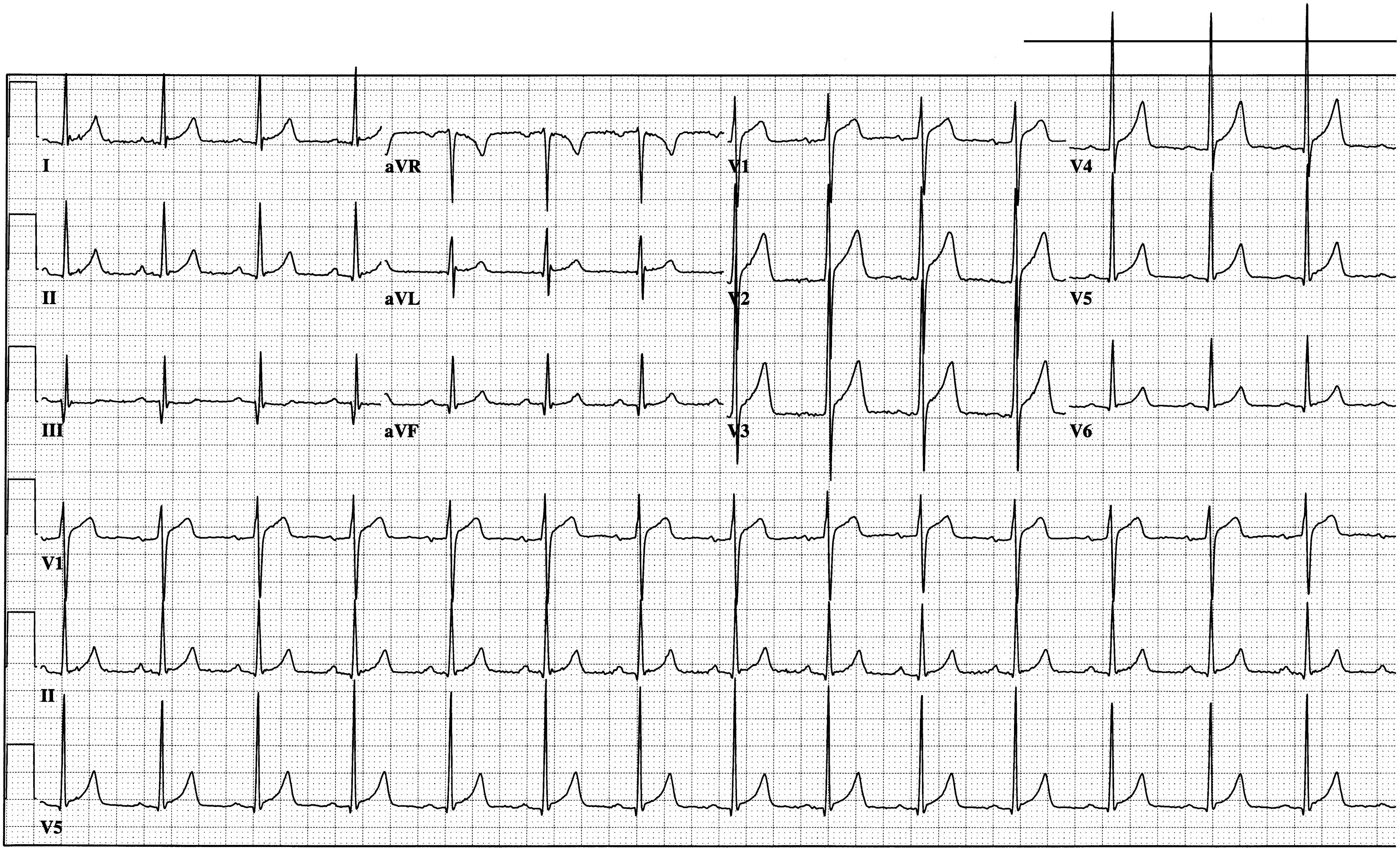
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

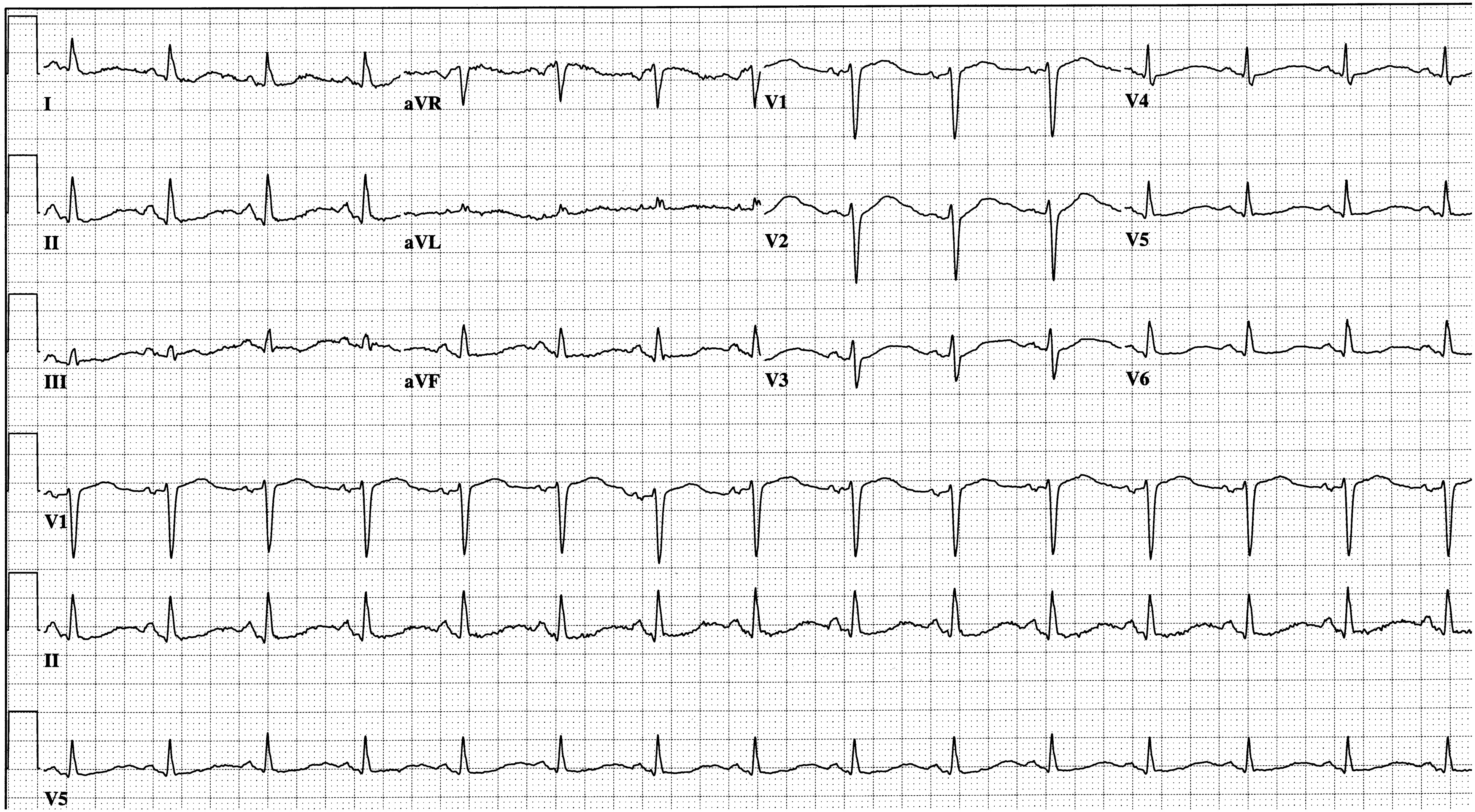
P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG 18

Atrial rate: ____	QRS complex:	ST segment: ____
Ventricular rate: ____	Axis: ____	T wave: ____
Rhythm: ____	Duration: ____	QT interval: ____
P wave: ____	Voltage: ____	U wave: ____
PR interval: ____	Morphology: ____	Diagnosis: ____



ECG 19

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

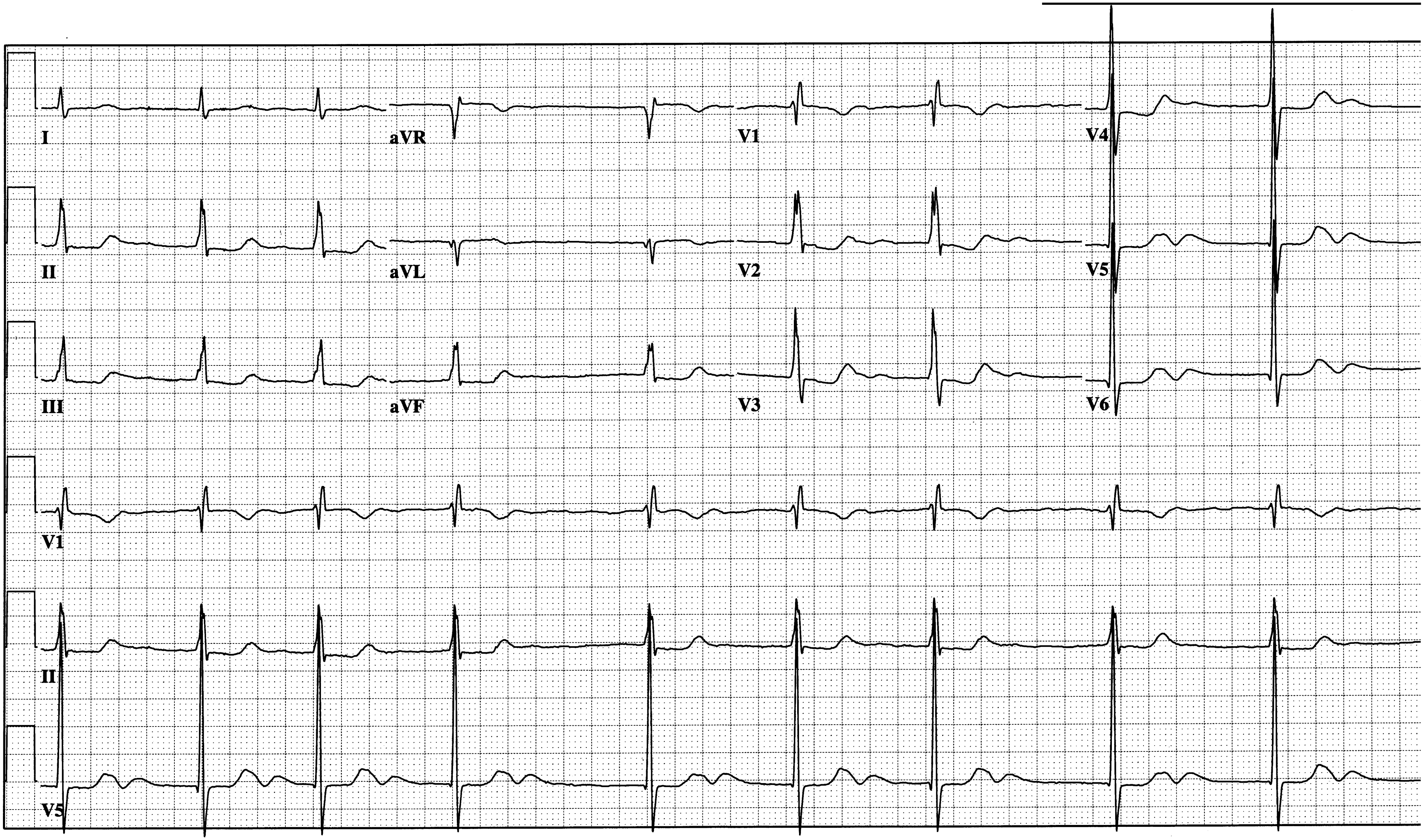
ST segment: ______

T wave: ______

QT interval: ______

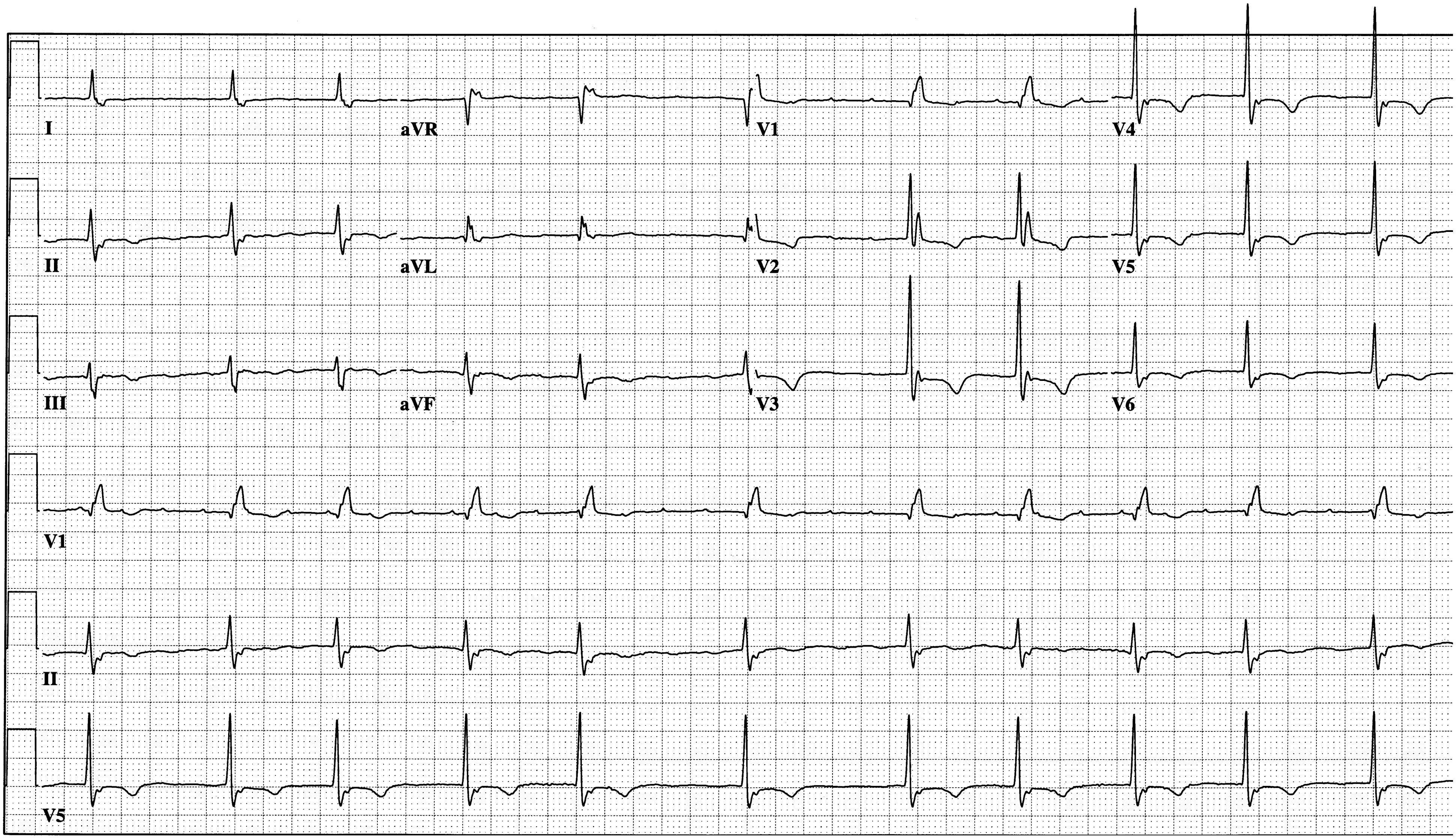
U wave: ______

Diagnosis: ______



ECG 20

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



Medication and Electrolyte Effects; Miscellaneous Conditions

Interpretations of Sample Tracings
ECG 1

Atrial rate: 74
Ventricular rate: 74
Rhythm: Sinus rhythm with occasional premature atrial complexes (PACs)
P wave: Normal
PR interval: 200 msec
QRS complex:
  Axis: 60°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Nonspecific changes
T wave: Deeply inverted in V_2 to V_4
QT interval: 470 msec
U wave:
Diagnosis: Sinus rhythm with frequent PACs, and diffuse T wave inversion and QT prolongation. This patient had a combination of severe metabolic and acid-base disorders, including a pH of 7.24, pCO_2 of 60 mm Hg, a serum calcium level of 6.6 mmol/l and a digoxin level of 2.6.

ECG 2

Atrial rate: 40
Ventricular rate: 40
Rhythm: Sinus bradycardia
P wave: Normal
PR interval: 280 msec
QRS complex:
  Axis: −60°
  Duration: 160 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Peaked in multiple leads
QT interval: 580 msec
U wave:
Diagnosis: Sinus bradycardia with first degree AV block, left axis deviation, a nonspecific intraventricular conduction defect (IVCD), and peaked T waves in multiple leads. This patient had acute renal failure and a serum potassium level of 6.5 mmol/l. The long PR interval, widened QRS, and peaked T waves are all typical of acute hyperkalemia.

ECG 3

Atrial rate: 70
Ventricular rate: 70
Rhythm: Sinus rhythm
P wave: Possible right atrial abnormality
PR interval: 140 msec
QRS complex:
  Axis: 300°
  Duration: 80 msec
  Voltage: Increased in the precordial leads
  Morphology: Normal
ST segment: Normal
T wave: Spectacular wide and tall T waves in the precordial leads
QT interval: 690 msec
U wave:
Diagnosis: Sinus rhythm with possible right atrial abnormality, Voltage criteria for LVH, and grossly abnormal T waves and a very prolonged QT interval. These changes are due to acute amphetamine toxicity.

ECG 4

Atrial rate: 65
Ventricular rate: 65
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 150 msec
QRS complex:
  Axis: 15°
  Duration: 80 msec
  Voltage: Increased in the precordial leads
  Morphology: Normal
ST segment: Normal
T wave: Peaked in V_2 to V_5
QT interval: 600 msec
U wave:
Diagnosis: Sinus rhythm with very prominent T waves and a long QT interval in this patient with one of the congenital long QT syndromes

ECG 5

Atrial rate: 50
Ventricular rate: 50
Rhythm: Sinus bradycardia
P wave: Normal
PR interval: 160 msec

QRS complex:
Axis: 75°
Duration: 90 msec
Voltage: Normal
Morphology: Tall R wave in V_2
ST segment: Hyperacute ST segment elevation in II, III, aVF, V_5, and V_6 with ST depression in aVR, aVL, V_1, and V_2
T wave: Inverted in multiple leads
QT interval: 460 msec
U wave:
Diagnosis: Sinus bradycardia with an acute inferolateral and posterior MI

ECG 6

Atrial rate: 60
Ventricular rate: 60
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 180 msec
QRS complex:
Axis: −30°
Duration: 180 msec, LBBB
Voltage:
Morphology:
ST segment:
T wave:
QT interval: 510 msec
U wave:
Diagnosis: Sinus rhythm with LBBB. LBBB is one of the causes of ST segment elevation, which can be seen here in V_1 to V_4

ECG 7

Atrial rate: 60
Ventricular rate: 60
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 200 msec
QRS complex:
Axis: 60°
Duration: 90 msec
Voltage: Increased in the precordial leads
Morphology: Normal
ST segment: Nonspecific changes
T wave: Normal
QT interval: 420 msec

U wave:
Diagnosis: Sinus rhythm with voltage criteria for LVH. The ST segment elevation in V_1 to V_3 is typical of patients with LVH.

ECG 8

Atrial rate: 76
Ventricular rate: 76
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 140 msec
QRS complex:
  Axis: 20°
  Duration: 90 msec
  Voltage: Normal
  Morphology: Deep Q waves in V_1 to V_3
ST segment: Elevated in V_1 to V_4
T wave: Deeply inverted in V_2 to V_5
QT interval: 420 msec
U wave:
Diagnosis: Sinus rhythm with a previous anteroseptal MI. In this case, an ECG from 6 months prior showed similar findings, implying that the residual ST elevation indicates an LV aneurysm.

ECG 9

Atrial rate: 58
Ventricular rate: 58
Rhythm: Sinus bradycardia
P wave: Normal
PR interval: 100 msec
QRS complex:
  Axis: 90°
  Duration:
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval: 440 msec
U wave:
Diagnosis: Sinus bradycardia with WPW. The tall R waves in V_1 and V_2 are consequences of this diagnosis.

ECG 10

Atrial rate:
Ventricular rate: 46
Rhythm: Junctional rhythm
P wave:
PR interval:
QRS complex:
  Axis: 75°
  Duration: 110 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Diffuse sagging
T wave: Normal
QT interval: 490 msec
U wave: Prominent U waves in V_2 to V_5
Diagnosis: Junctional rhythm with aging ST segment depression. This morphology of ST depression is frequently associated with digoxin therapy.

ECG 11

Atrial rate: 71
Ventricular rate: 71
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 240 msec
QRS complex:
  Axis: –75°
  Duration: 140 msec, RBBB, LAFB
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Deeply inverted in multiple leads
QT interval: 650 msec
U wave:
Diagnosis: Sinus rhythm with first degree AV block, left axis deviation, RBBB, left anterior fascicular block (left axis deviation ≥45°, tiny Q waves in I, aVL, and an IVCD), diffuse deep T wave inversion, and a prolonged QT. This patient had clinical evidence of acute ischemia when this ECG was obtained.

ECG 12

Atrial rate: 70
Ventricular rate: 70
Rhythm: Sinus rhythm
P wave: Normal

PR interval: 160 msec
QRS complex:
Axis: 75°
Duration: 80 msec
Voltage: Normal
Morphology: Tall R waves in V_1 and V_2
ST segment: Subtle ST elevation in V_5 and V_6 and ST depression in V_1 to V_3
T wave: Rather tall in V_1 to V_3
QT interval: 380 msec
U wave:
Diagnosis: Sinus rhythm with an acute posterior and lateral MI

ECG 13

Atrial rate: 120
Ventricular rate: 120
Rhythm: Sinus tachycardia
P wave: Normal
PR interval: 140 msec
QRS complex:
Axis: 45°
Duration: 80
Voltage: Normal
Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 280 msec
U wave:
Diagnosis: Sinus tachycardia with a substantial amount of baseline artifact. P waves are most readily seen in III.

ECG 14

Atrial rate: 72
Ventricular rate: 72
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 180 msec
QRS complex:
Axis: −20°
Duration: 95
Voltage: Normal
Morphology: Q waves in aVF and a tall R wave in V_2
ST segment: Normal
T wave: Normal
QT interval: 380 msec

U wave:
Diagnosis: Sinus rhythm with a previous inferoposterior MI

ECG 15

Atrial rate: 120
Ventricular rate: 120
Rhythm: Sinus tachycardia
P wave: Normal
PR interval: 140 msec and depressed in II
QRS complex:
 Axis: 60°
 Duration: 80 msec
 Voltage: Normal
 Morphology: Normal
ST segment: Diffuse ST segment elevation
T wave: Normal
QT interval: 420 msec
U wave:
Diagnosis: Sinus tachycardia with acute pericarditis

ECG 16

Atrial rate:
Ventricular rate: 160
Rhythm:
P wave:
PR interval:
QRS complex:
 Axis: 110°
 Duration: 140 msec
 Voltage:
 Morphology:
ST segment:
T wave: Extremely pointed in V_2 to V_4
QT interval: 320 msec
U wave:
Diagnosis: This is a wide complex tachycardia with RS complex present in the precordial leads. None of the RS intervals are >100 msec. There is no discernable atrial activity. The monophasic R wave in V_6 is consistent with a supraventricular rhythm with LBBB aberrancy. The rhythm may be sinus tachycardia or possibly atrial flutter with 2:1 AV conduction. The dramatic pointed T waves are impressive even in the face of LBBB in this patient with a serum potassium level of 8.8 mmol/l.

ECG 17

Atrial rate: 85
Ventricular rate: 85
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: 45°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Mild diffuse ST segment elevation
T wave: Normal
QT interval: 330 msec
U wave:
Diagnosis: Sinus rhythm with early repolarization. There is no other obvious pathological ST elevation.

ECG 18

Atrial rate: 85
Ventricular rate: 85
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 140 msec
QRS complex:
  Axis: 45°
  Duration: 90 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 500 msec
U wave:
Diagnosis: Sinus rhythm with a very long QT interval. This patient had a serum potassium level of 1.8 mmol/l.

ECG 19

Atrial rate:
Ventricular rate: 55
Rhythm: Atrial fibrillation
P wave:
PR interval:

QRS complex:
Axis: 75°
Duration: 100 msec
Voltage: Increased in the precordial leads
Morphology: Normal
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 500 msec
U wave: Extremely prominent U waves in V_2 to V_6
Diagnosis: Atrial fibrillation with possible LVH by voltage criteria, a RSR' pattern in V_1 consistent with an incomplete RBBB, nonspecific ST-T wave changes, and an extremely prominent U wave. This patient had a serum potassium level of 2.2 mmol/l.

ECG 20

Atrial rate: 216
Ventricular rate: 66
Rhythm: Atrial tachycardia with variable AV block
P wave:
PR interval:
QRS complex:
Axis: 0°
Duration: 125 msec, RBBB
Voltage: Normal
Morphology: Normal
ST segment: Normal
T wave: Inverted in V_3 to V_6
QT interval: 420 msec
U wave:
Diagnosis: Atrial tachycardia with variable AV block, RBBB, and nonspecific T wave changes. This rhythm is frequently encountered in patients with digoxin toxicity.

Day 10

Electronic Pacemakers

I. Pacemaker nomenclature—a standardized 5-letter code, recently designated "NBG", has been developed to indicate various pacemaker functions.

A. The first letter refers to the chamber(s) to which pacing stimuli are delivered
   1. A = atrium
   2. V = ventricle
   3. D = dual or both chambers
   4. O = no pacing support (early implantable defibrillators, which also used this coding system, had no pacing function)

B. The second letter refers to the chamber(s) in which sensing can occur
   1. A = atrium
   2. V = ventricle
   3. D = dual or both chambers
   4. O = no sensing

C. The third letter refers to the mode of sensing or how the pacemaker reacts to a detected event
   1. I = inhibited, the system inhibits the output and resets the timers in response to a detected event.
   2. T = triggered, the system delivers an output in response to a detected event.
   3. D = dual mode of sensing
      a. This action is specific for a dual chamber pacemaker.
      b. It can both inhibit and trigger, depending on how it is programmed and what happens in the two chambers.
   4. O = no mode response (this is the only option if there is no sensing).

D. The fourth letter refers to a hierarchy of increasingly more complex capabilities
   1. O = no programmability, no communicating capability and no rate modulation.
   2. P = simple programmability (one or two parameters).
   3. M = multiparameter programmability (three or more programmable options).

4. C = communicating or telemetric capability; these devices all have multiparameter programmability and are also able to transmit stored and real time intracardiac electrograms.
5. R = rate modulation; these devices incorporate all of the above and add the capacity to vary heart rate according to programmed algorithms.

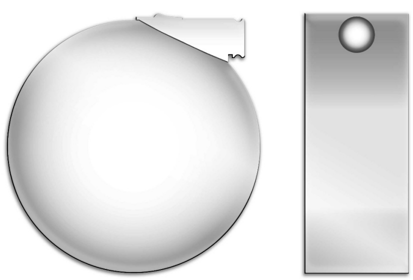
E. The fifth letter previously referred to antitachycardia functions such as overdrive pacing or the delivery of a shock, but currently refers to multisite pacing, thus:
   1. A = multisite pacing in the atria
   2. V = multisite pacing in the ventricles (as in biventricular pacemakers for heart failure)
   3. D = multisite pacing in the atria and ventricles
   4. O = no multisite pacemakers

F. Implantable cardiac defibrillators (ICDs) now have a separate coding system that is not covered in this text.

II. Pacemaker development

A. VOO (Day 10-01) (Day 10-02)
   1. The first pacemakers, developed in the late 1950s, had no sensing circuitry and paced in the ventricle at a rate set by the factory.
   2. The advantage of this system was that it was better than asystole.

Chamber Paced	Chamber Sensed	Activity
V	O	O



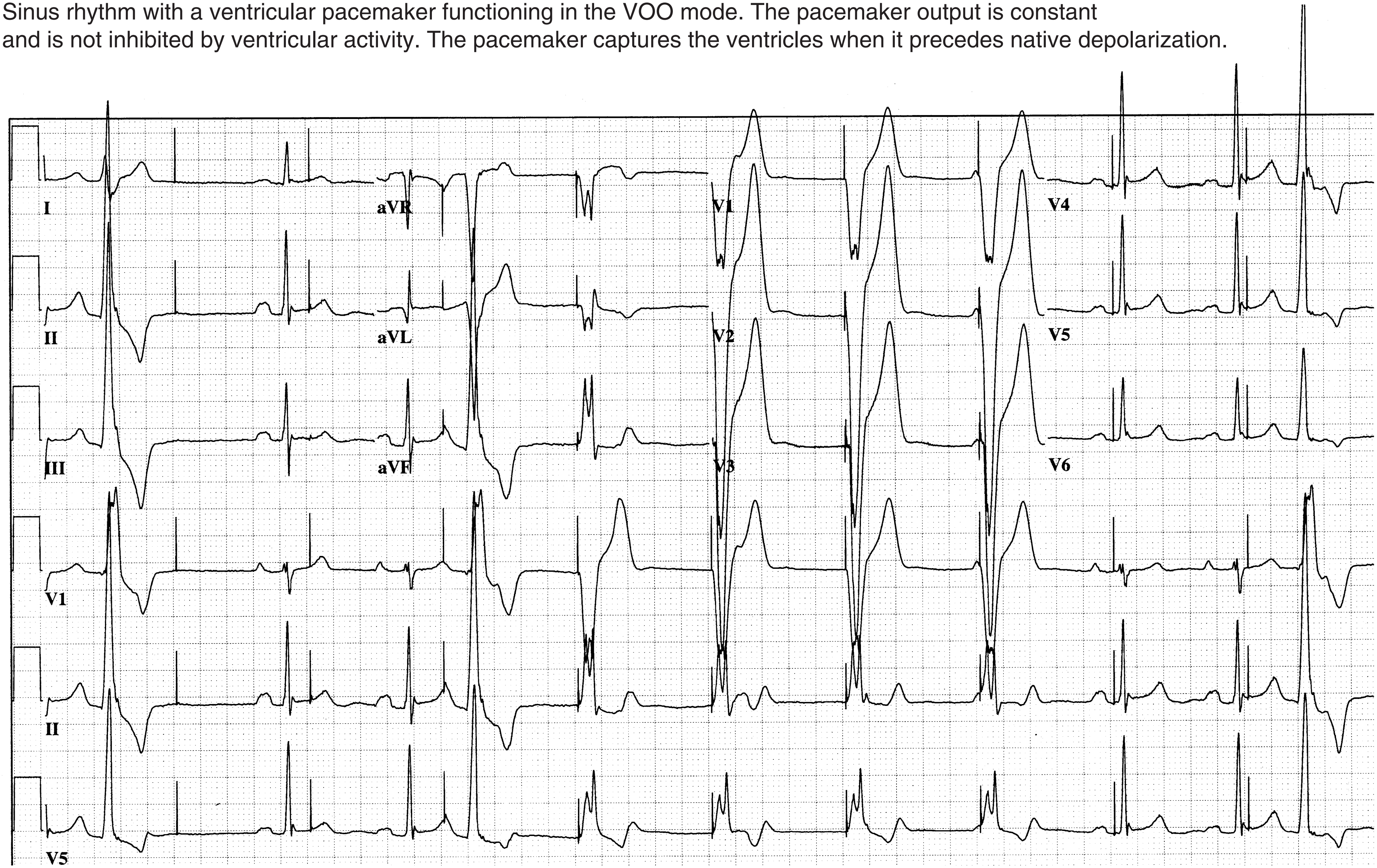
First generation pacemaker—paces in the ventricle, does not sense, and is neither triggered norinhibited. The pace maker is portrayed actual size from the front and side.

Problems associated with VOO mode:

A. "R on T" phenomenon
B. Uses battery constantly
C. Distorts all QRS complexes
D. No AV synchrony
E. No rate responsiveness

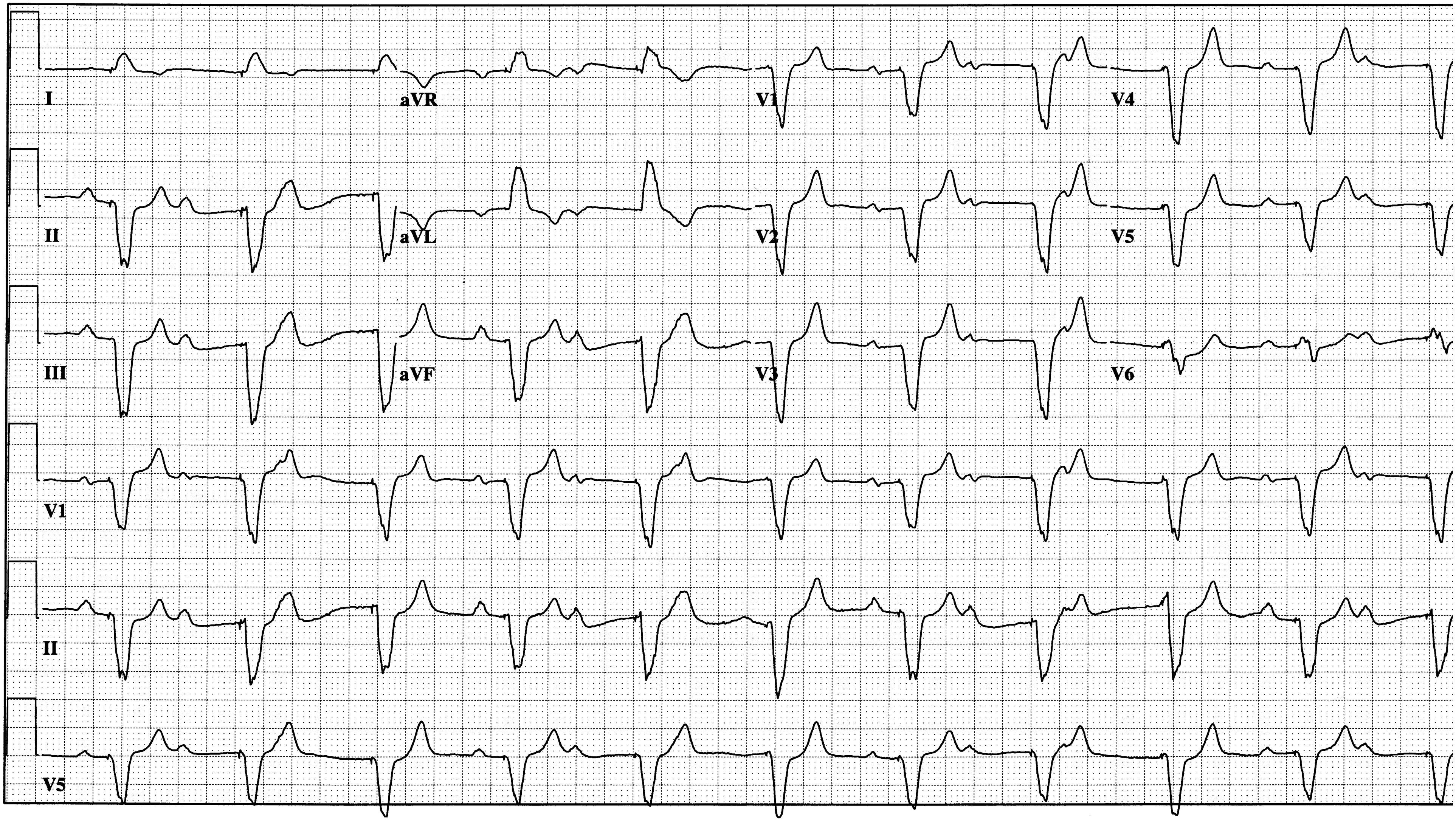
DAY 10-1

Sinus rhythm with a ventricular pacemaker functioning in the VOO mode. The pacemaker output is constant and is not inhibited by ventricular activity. The pacemaker captures the ventricles when it precedes native depolarization.



DAY 10-2

Sinus rhythm with complete heart block and a VOO pacemaker in which all of the ventricular depolarizations are initiated by the pacemaker. Note the Av dissociation, as the pacemaker is not sensing atrial activity.



3. A modern pacemaker can still be programmed to this modality, which may be useful under certain circumstances (e.g., during surgery when signals from electrocautery might be inappropriately inhibit the pacemaker).

B. VVT (Day 10-03)
1. This pacemaker sensed in the ventricle, but was committed to firing.
2. This technology solved the potential problem of possible initiation of a ventricular arrhythmia by avoiding firing on the upslope of the T wave.
3. The problems of distortion of the QRS complexes and constant use of the battery remained.

Chamber Paced	Chamber Sensed	Activity
V	O	O
V	V	T

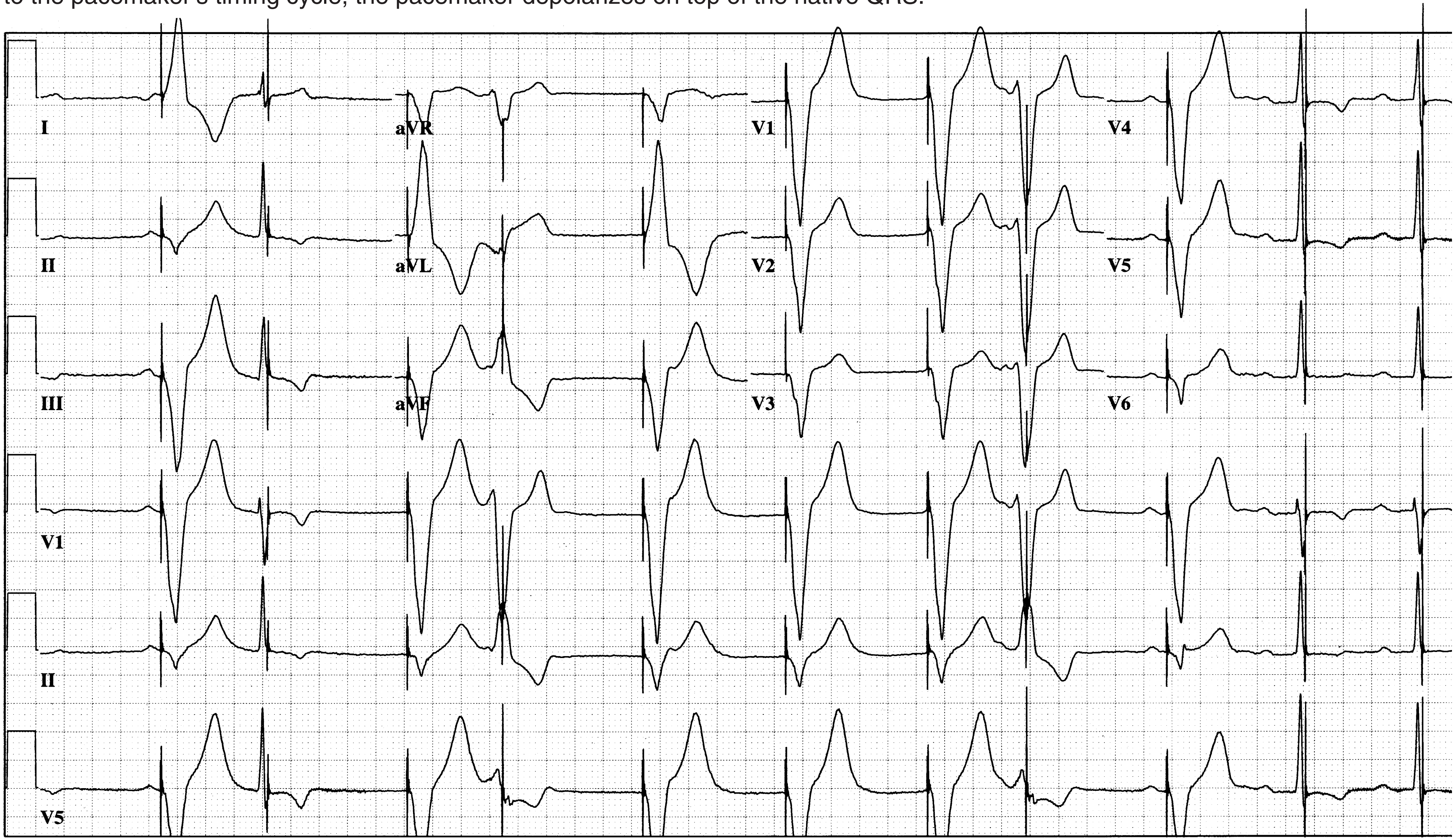
Second generation pacemaker—paces in the ventricle, senses in the ventricle, and is triggered. The pacemaker is portrayed actual size.

Problems associated with VVT mode:

A. ~~“R on T” phenomenon~~
B. Uses battery constantly
C. Distorts all QRS complexes
D. No AV synchrony
E. No rate responsiveness

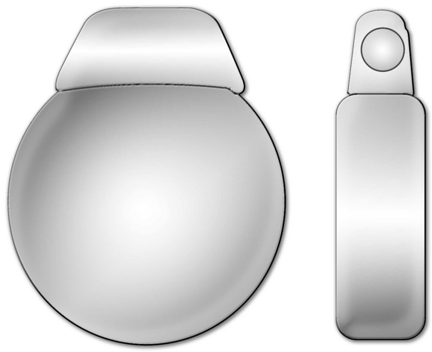
DAY 10-3

Sinus rhythm with a ventricular pacemaker functioning in the VVT mode. Note that if there is a native QRS complex that occurs prior to the pacemaker's timing cycle, the pacemaker depolarizes on top of the native QRS.



C. VVI (Day 10-04) (Day 10-05)
   1. This pacemaker sensed in the ventricle and fired only if a ventricular beat did not occur during the programmed timing cycle.
   2. This technology had the potential to decrease battery utilization and deformation of every QRS complex.

Chamber Paced	Chamber Sensed	Activity
V	O	O
V	V	T
V	V	I



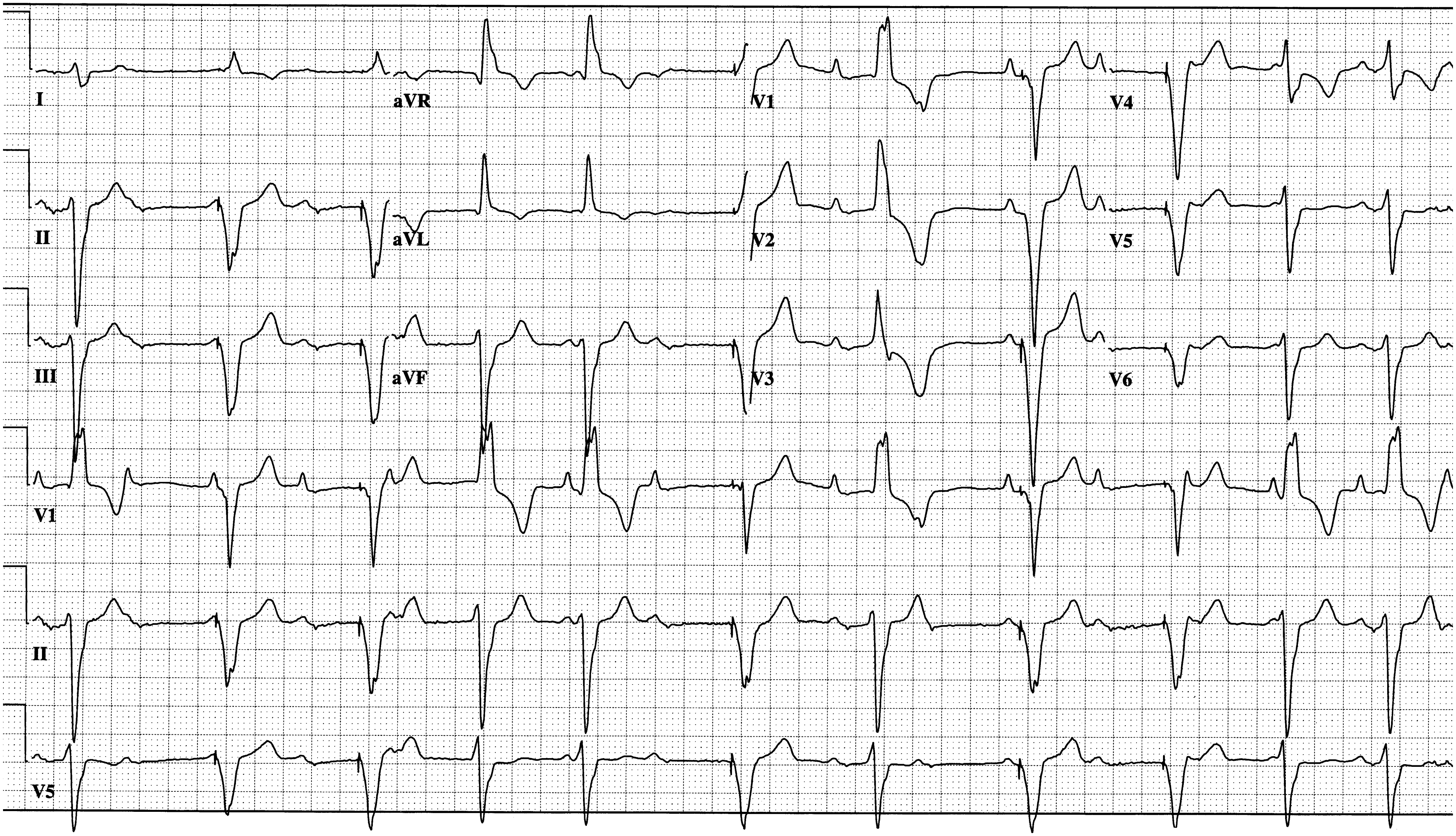
Third generation pacemaker—paces in the ventricle, sense in the ventricle, and is inhibited. The basic rate is programmable. Pacemaker is portrayed actual size from front and side.

Problems associated with VVT mode:

A. ~~"R on T" phenomenon~~
B. ~~Uses battery constantly~~
C. ~~Distorts all QRS complexes~~
D. No AV synchrony
E. No rate responsiveness

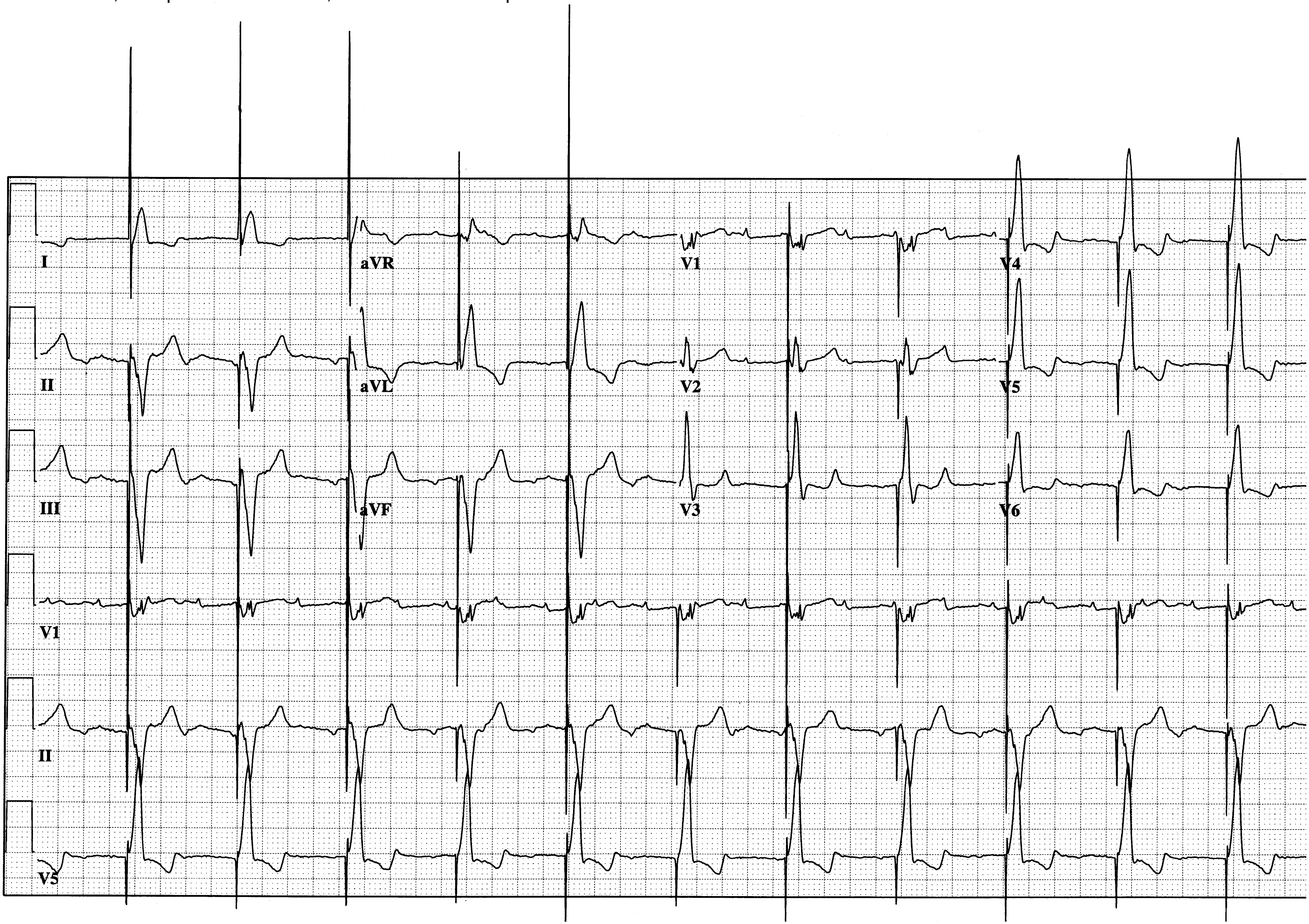
DAY 10-4

Sinus rhythm with complete heart block, occasional junctional escape beats, and an appropriately functioning VVI pacemaker. Note that if a native QRS comples occurs within the pacemaker's programmed rate, ventricular pacing is inhibited. This pacemaker is incapable of tracking the patient's own atrial activity and does not allow for the utillization of atrial systole in filling the ventricies.



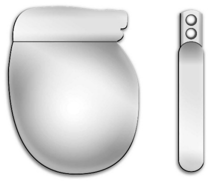
DAY 10-5

Atrial flutter, complete heart block, and a ventricular pacemaker



D. AV sequential pacemakers

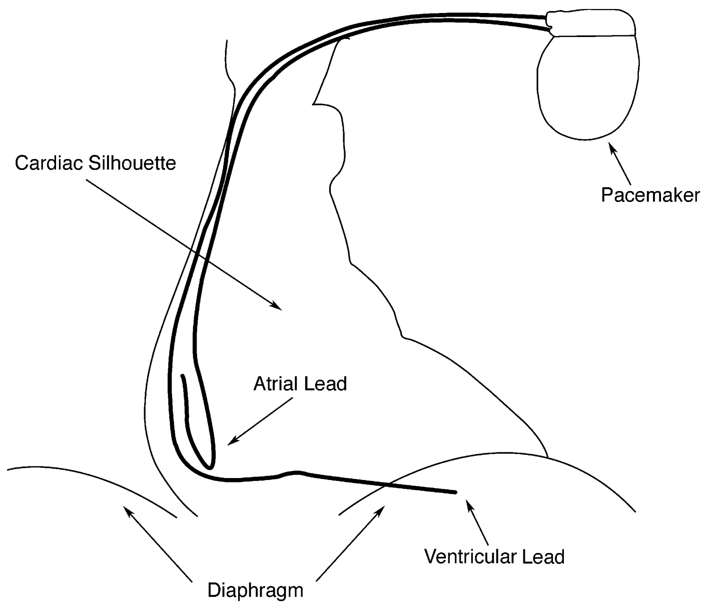
Chamber Paced	Chamber Sensed	Activity
V	O	O
V	V	T
V	V	I
D	D	D



Fourth generation pacemaker—paces in the atrium and ventricle, senses in the atrium and ventricle, and can be programmed to be inhibited or triggered. The pacemaker is portrayed actual size.

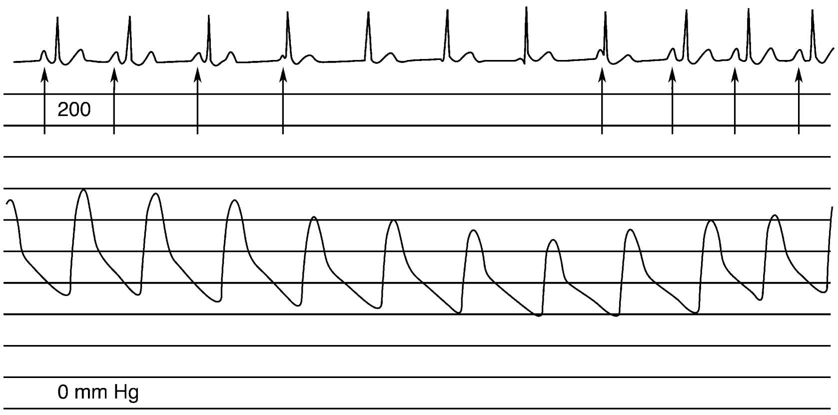
Problems associated with DDD mode:

A. ~~"R on T" phenomenon~~
B. ~~Uses battery constantly~~
C. ~~Distorts all QRS complexes~~
D. ~~No AV synchrony~~
E. No rate responsiveness



Outline of a chest x-ray showing the location of a DDD pacemaker and the atrial and ventricular leads. Note the atrial lead curled in the right atrium and lodged in the atrial appendage. The ventricular lead is typically in the RV apex, although the use of nonstandard locations, such as the interventricular septum, is becoming more common.

1. AV sequential pacemakers, often referred to by the code DDD (for "Dual, Dual, Dual"), pace and sense in the atrium and the ventricle, and can be inhibited or triggered.
2. AV sequential pacemakers allow AV synchrony, which may substantially improve stroke volume. (Day 10-06) (Day 10-07)

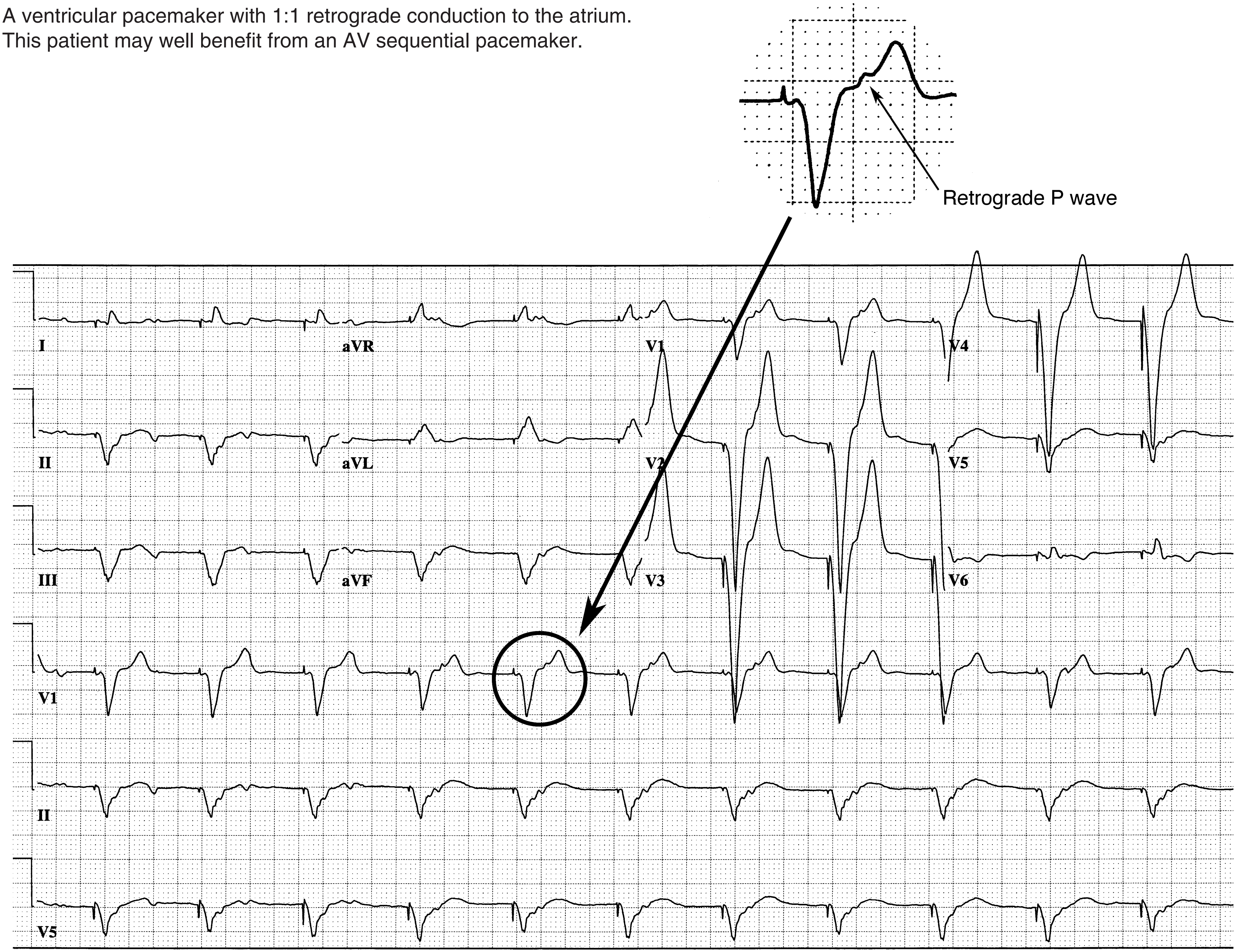


Simultaneous Lead II rhythm strip and arterial pressure in a patient undergoing cardiac catheterization. In the center of the strip, he spontaneously developed sinus bradycardia with a junctional escape rhythm (P waves are indicated by the arrows). The temporary loss of AV synchrony produced a substantial decrease in the arterial blood pressure. In some patients, stroke volume may fall as much as 30% with loss of AV synchrony.

3. There are two basic intervals that must be programmed:
   a. The V-V interval—this is the time between ventricular depolarizations, or the basic heart rate.
   b. The A-V delay—this is the time between atrial and ventricular depolarization.
4. With the V-V interval and A-V delay programmed, there are four possible responses by the pacemaker (Day 10-08) (Day 10-09) (Day 10-10) (Day 10-11) (Day 10-12) (Day 10-13) (Day 10-14)

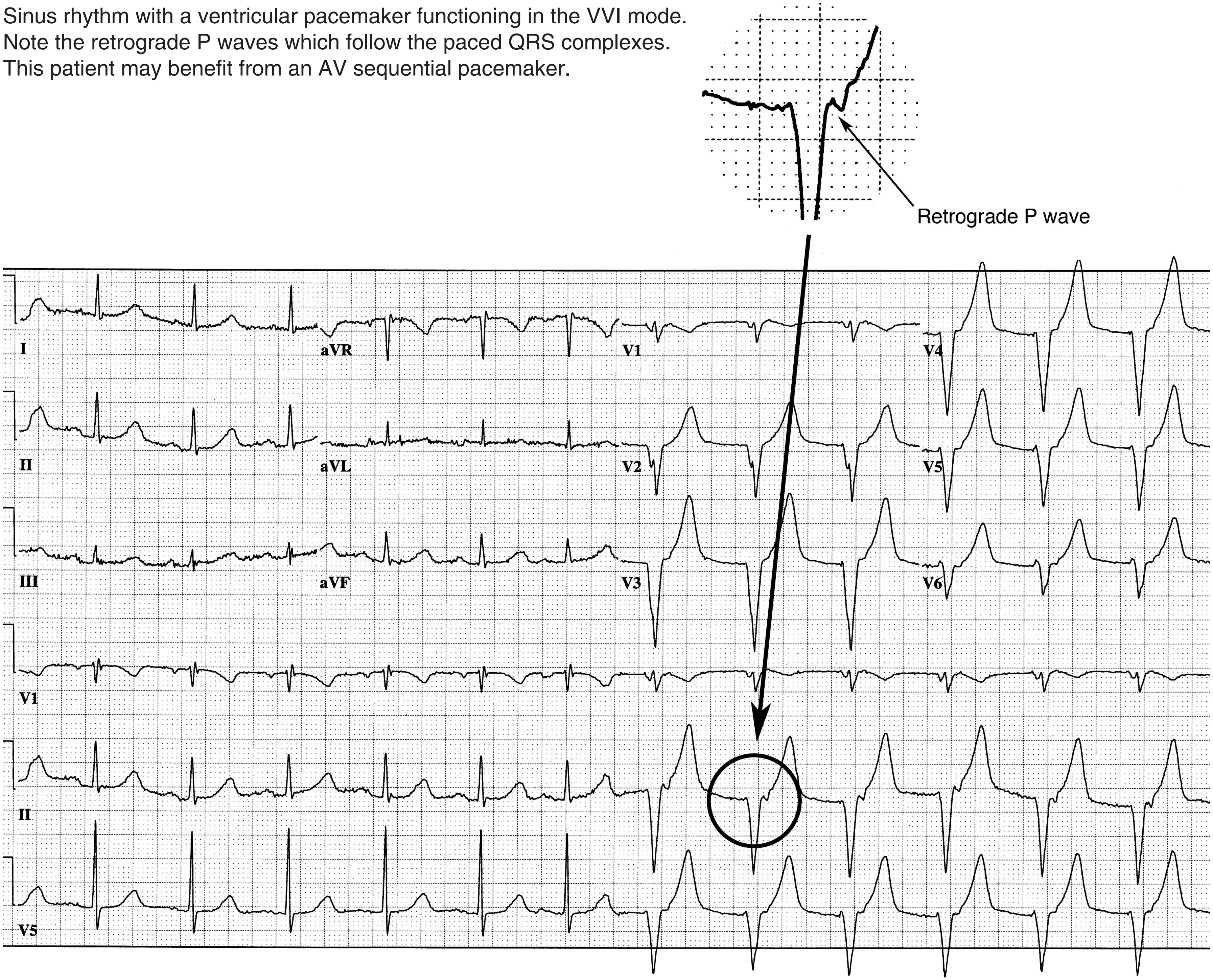
DAY 10-6

A ventricular pacemaker with 1:1 retrograde conduction to the atrium. This patient may well benefit from an AV sequential pacemaker.



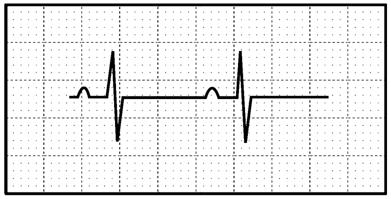
DAY 10-07

Sinus rhythm with a ventricular pacemaker functioning in the VVI mode.
Note the retrograde P waves which follow the paced QRS complexes.
This patient may benefit from an AV sequential pacemaker.

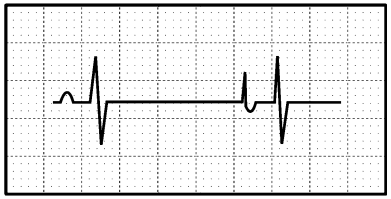


DAY 10-08

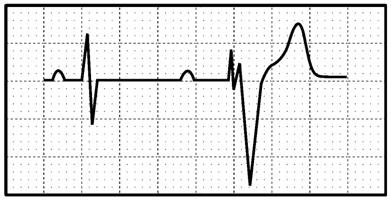
Response 1—the patient's own QRS starts the V-V clock. The pacemaker knows that a P wave must occur within 800 msec (1000 minus 200). In this case, a native P wave inhibits the atrial pacemaker, so no atrial spike is seen. The patient has his own ventricular depolarization within 200 msec which inhibits the ventricular pacemaker. No ventricular spike is seen.



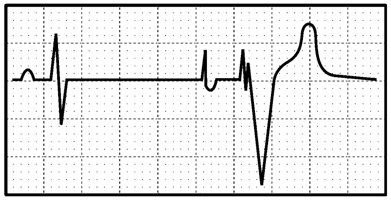
Response 2—in this case, a P wave does not occur within 800 msec, so the atrial pacemaker discharges and produces an odd-axis P wave. The A-V clock starts, the patient has his own ventricular depolarization within 200 msec and inhibits the ventricular pacemaker. No ventricular spike is seen.



Response—in this case, a P wave does occur within 800 msec, so the atrial pacemaker is inhibited. The A-V clock starts, but there is no native ventricular depolarization within 200 msec and the ventricular pacemaker discharges, producing a wide QRS complex.



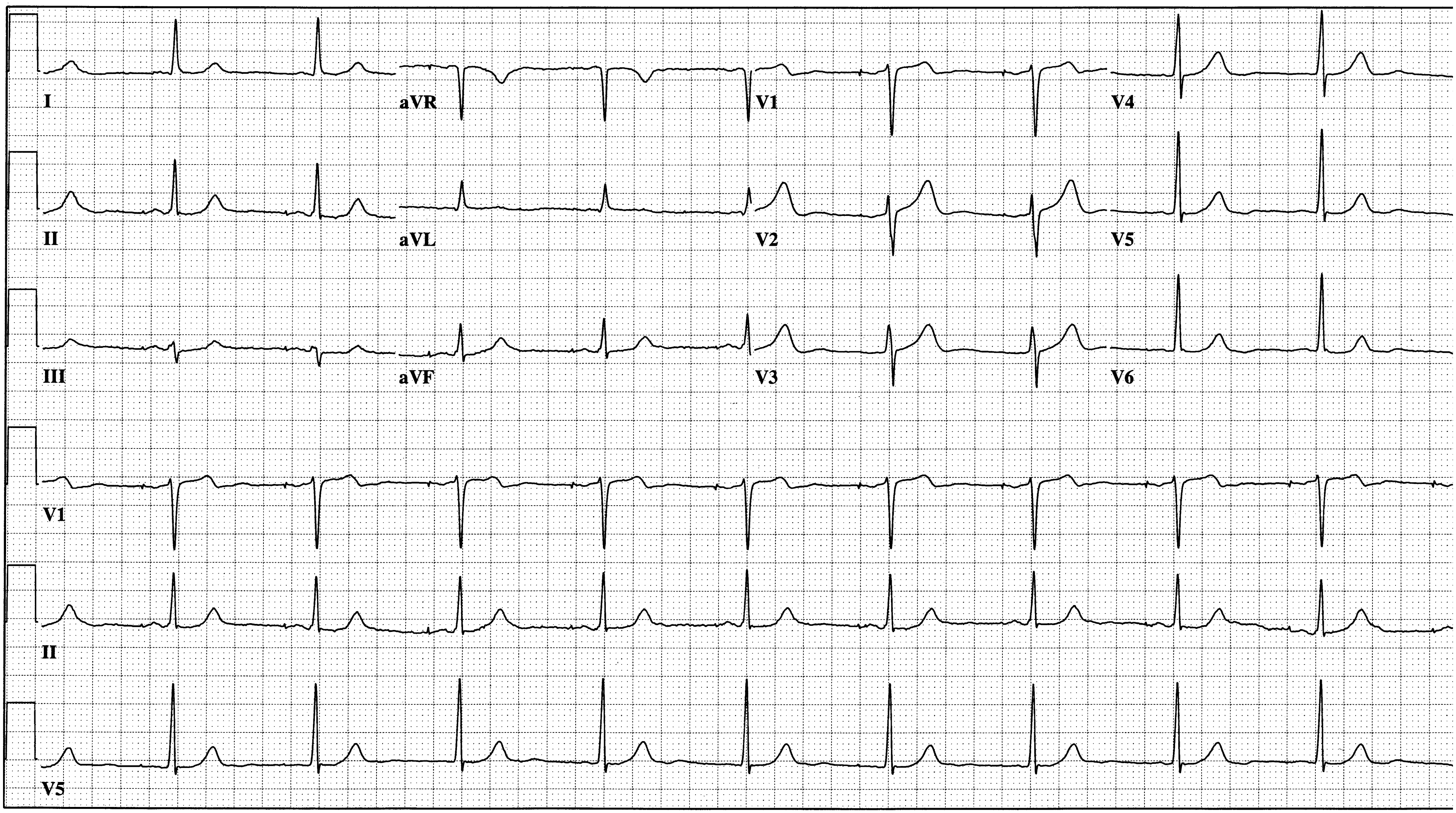
Response 4—in this case, a P wave does not occur within 800 msec, so the atrial pacemaker discharges and produces an odd-axis P wave. The A-V clock starts, but there is no native ventricular depolarization within 200 msec and the ventricular pacemaker discharges, producing a wide QRS complex.



The four types of response by an AV sequential pacemaker programmed with a V-V interval of 1000 msec (1 sec; heart rate of 60) and an A-V delay of 200 msec.

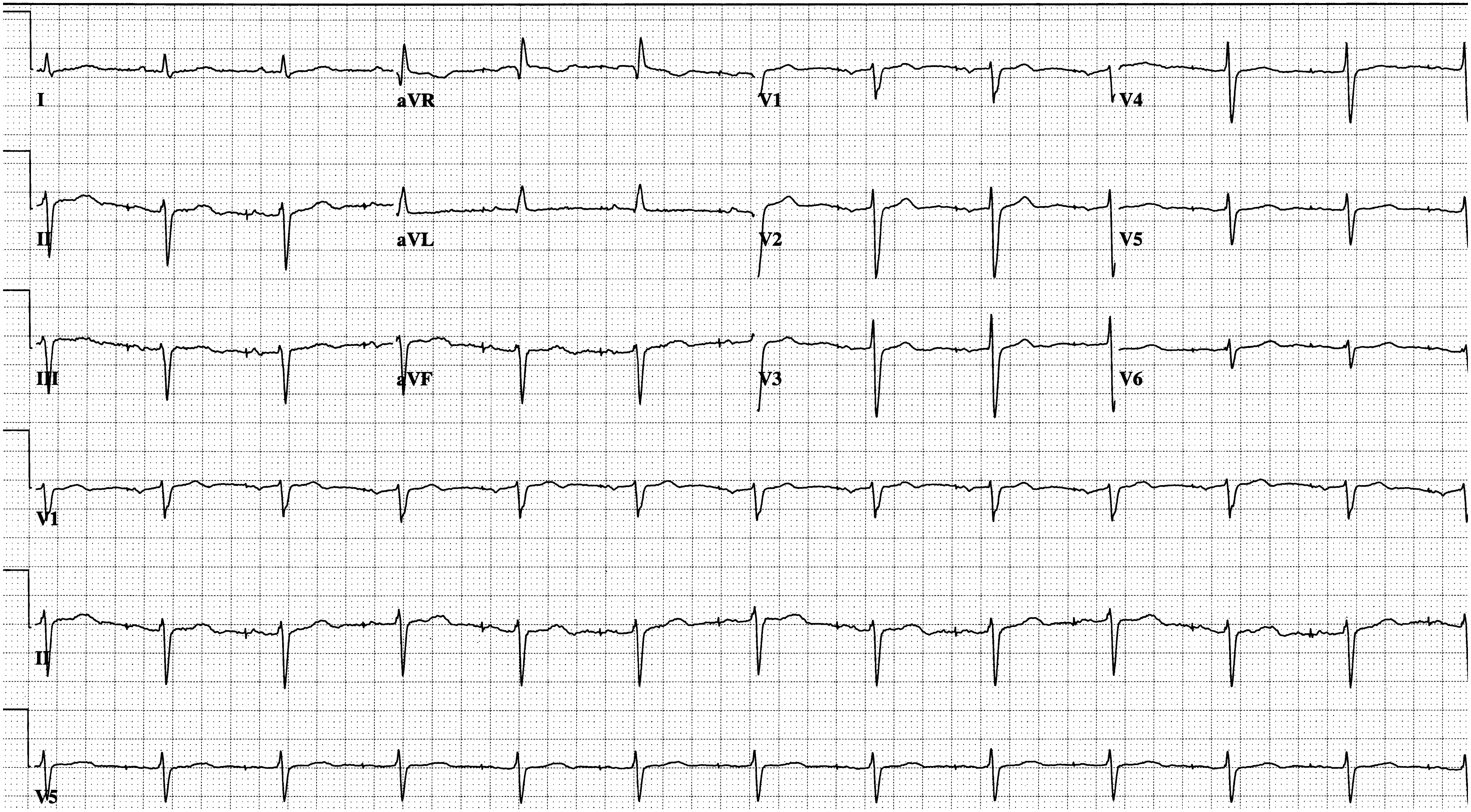
DAY 10-09

An AV sequential pacemaker that is pacing in the atrium and is tracking the patient’s native ventricular depolarization



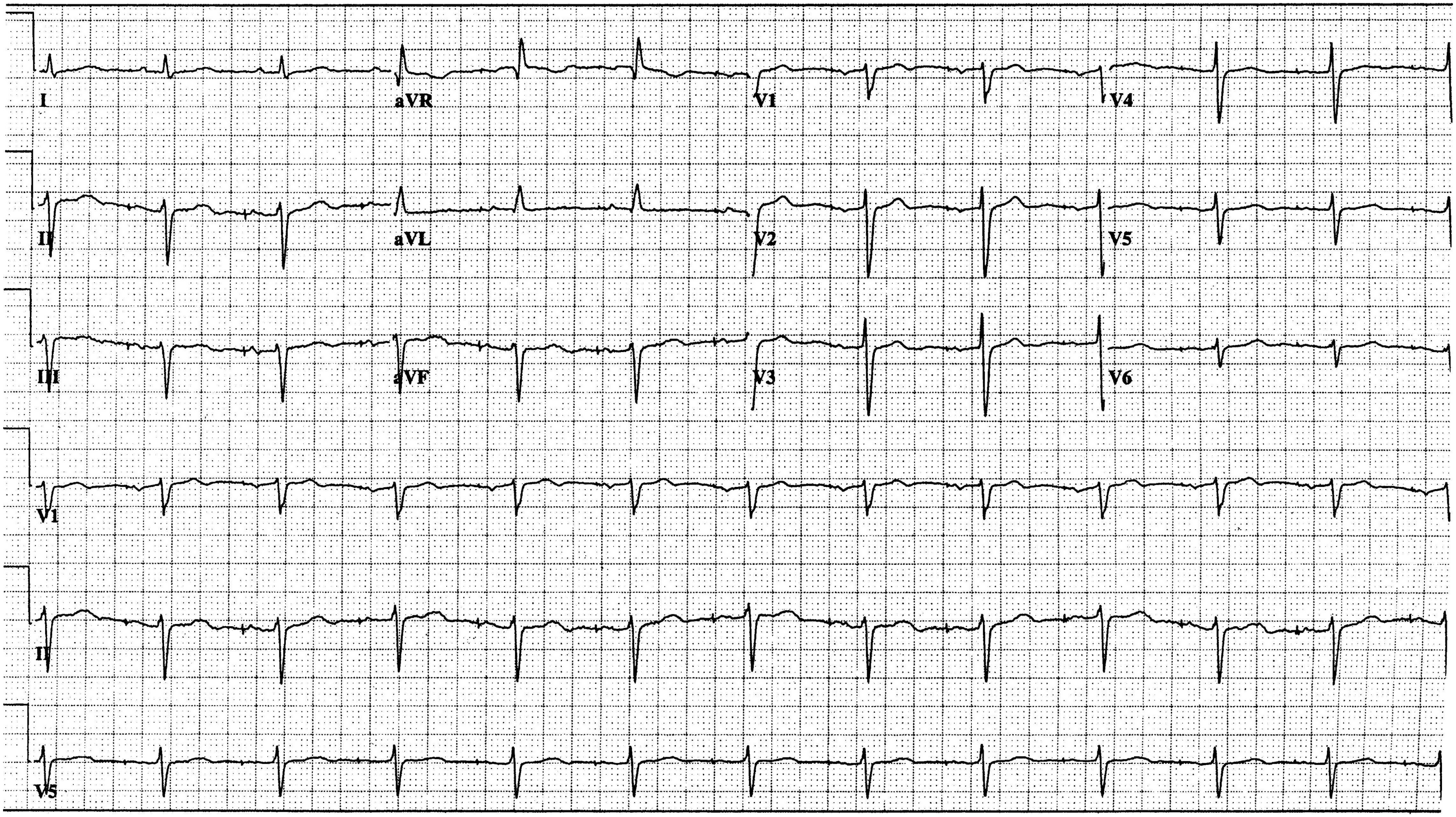
DAY 10-10

An AV sequential pacemaker that is pacing in the atrium and is tracking the patient's native ventricular depolarization



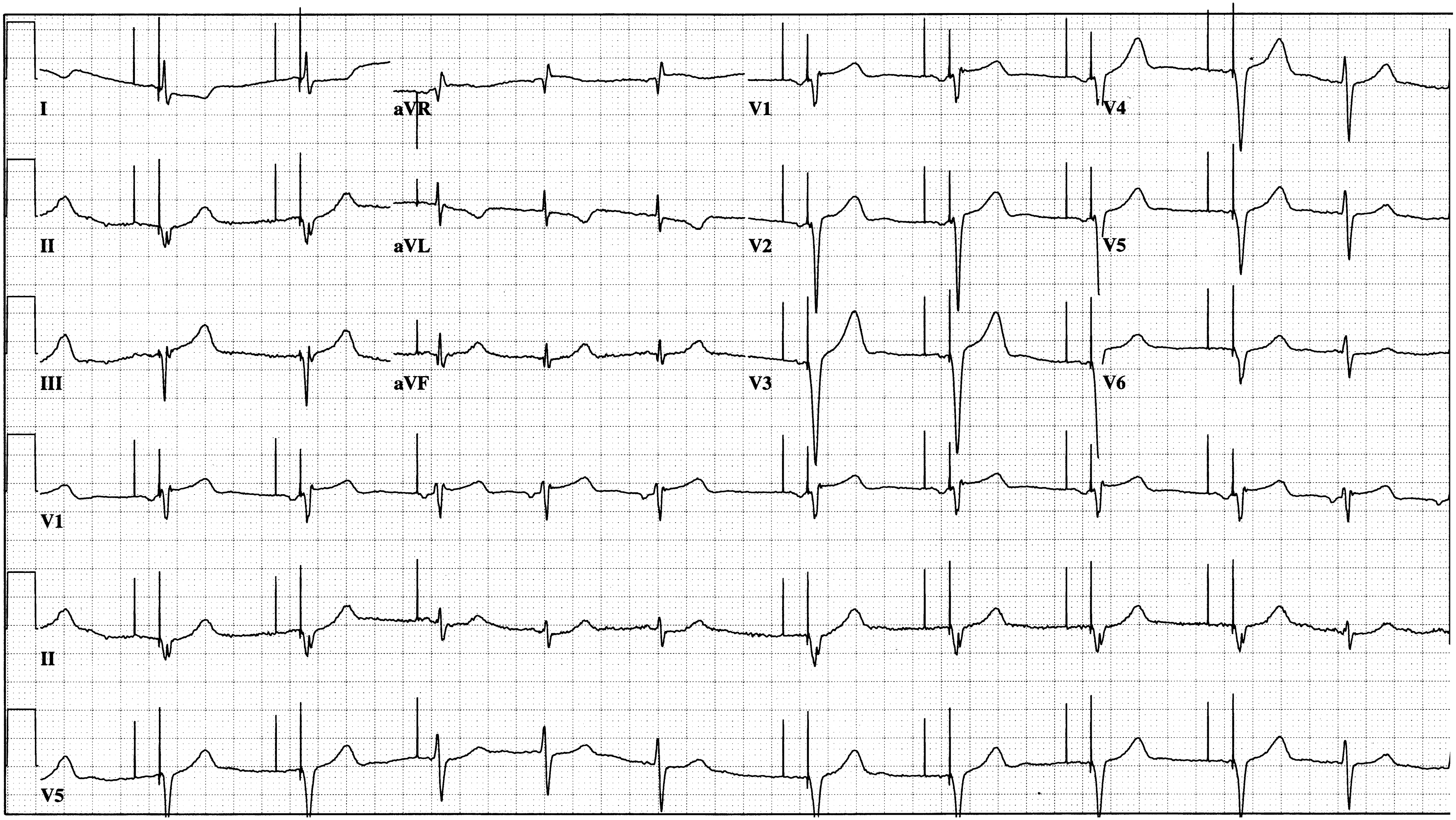
DAY 10-11

An AV sequential pacemaker that is pacing in the atrium and is tracking the patient's native ventricular depolarization



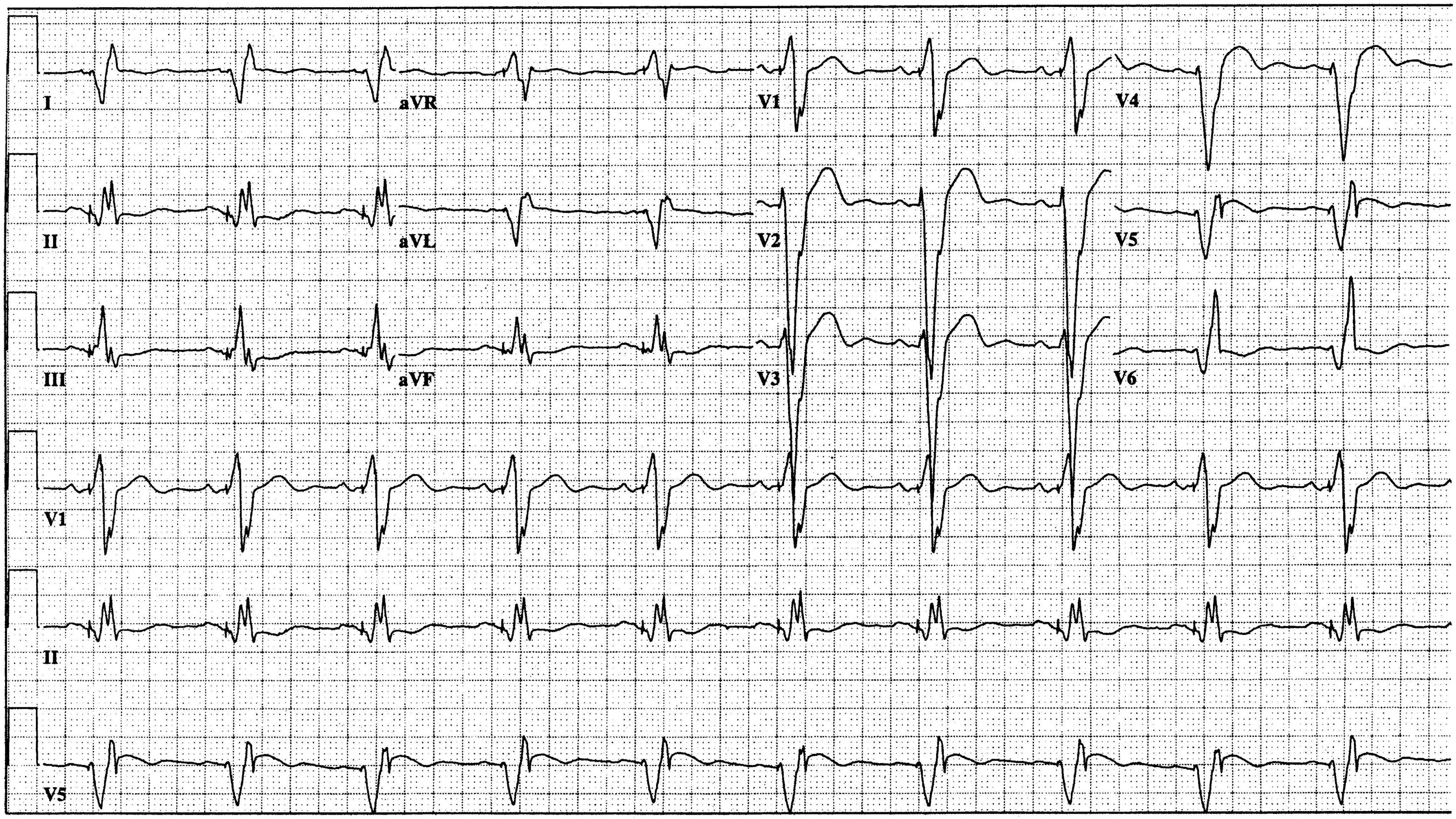
DAY 10-12

An AV sequential pacemaker that is appropriately inhibited by the patient's own atrial and ventricular activity



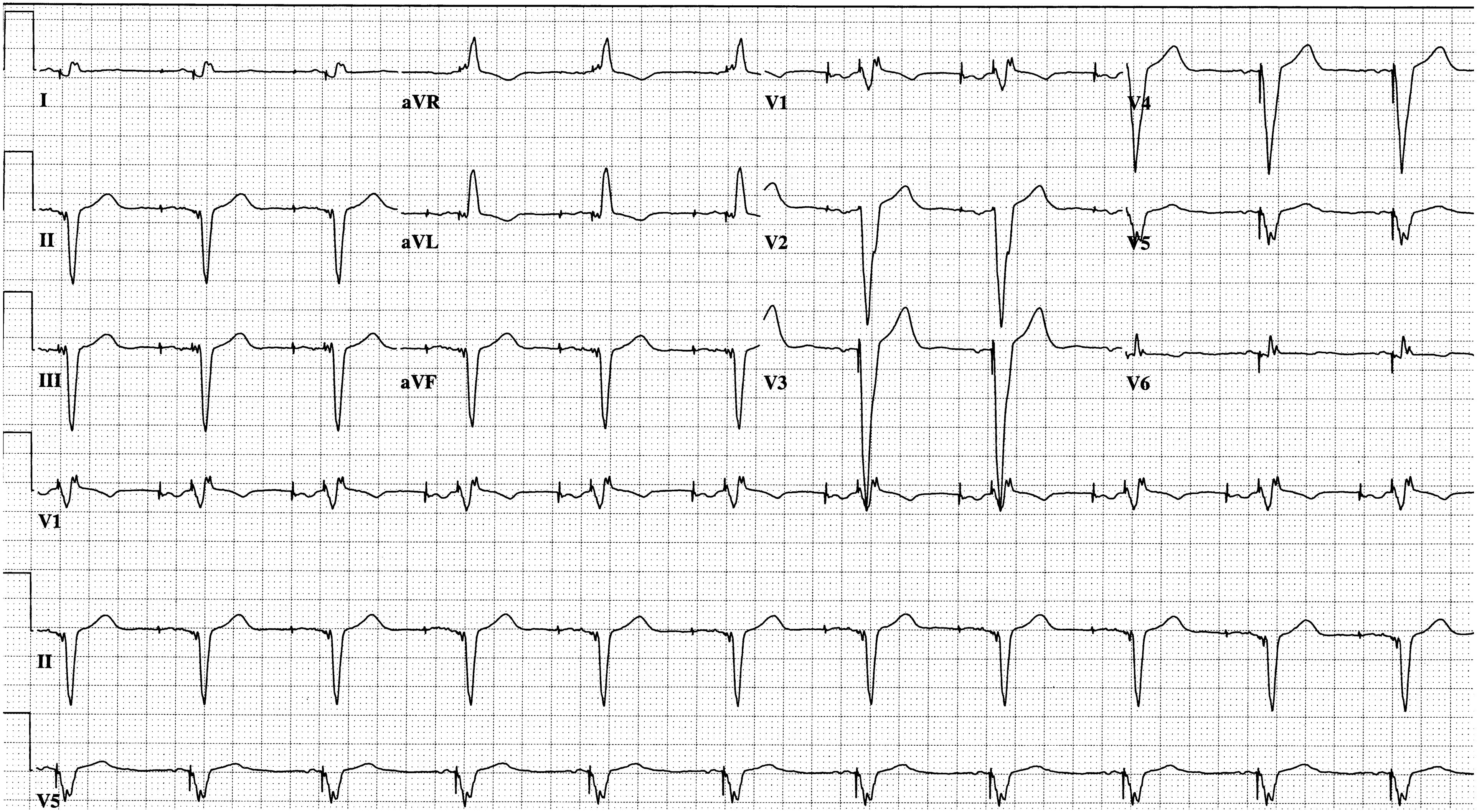
DAY 10-13

An AV sequential pacemaker that is tracking the patient's atrial rhythm and pacing in the ventricle



DAY 10-14

AV sequential pacing utilizing both the atrial and ventricular pacemakers



E. Pacemakers with multiple parameters (Day 10-15)
1. The latest pacemakers have many programmable features.
2. Some devices are capable of adjusting intervals, such as the AV delay, in response to changes in heart rate or other parameters.
3. Many devices are capable of recording, storing, and transmitting intracardiac electrograms.
4. Rate responsiveness
   a. The heart rate may be modulated in response to exercise.
   b. One method of detecting exercise is by sensing increasing movement of the pacemaker secondary to underlying pectoral muscle activity.
   c. Another method involves sensing increasing intrathoracic impedance associated with the hyperventilation of exercise.
   d. When exercise ceases, the heart rate slows down gradually, again according to programmed parameters.
   e. Both VVI and DDD pacemakers can utilize this technology.

Chamber Paced	Chamber Sensed	Activity	Program-mability
V	O	O	
V	V	T	
V	V	I	R
D	D	D	R

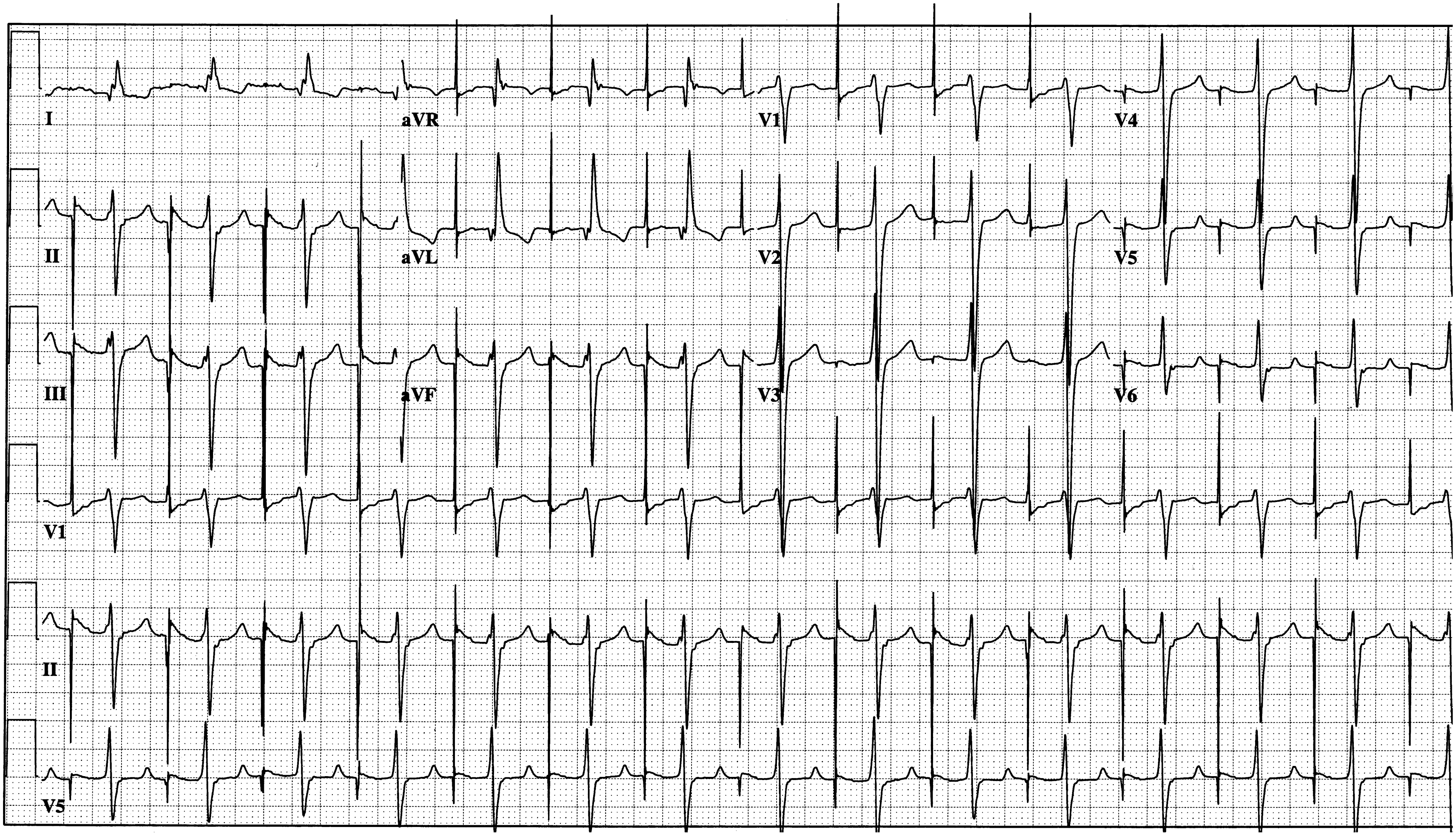
Fifth generation pacemakers—these devices have the ability to detect increasing physical activity by the patient, usually by sensing increasing pacemaker motion with contraction of the underlying pectoral muscle, or by sensing increasing impedance between the pacemaker and the electrode caused by hyperventilation. Both VVI and DDD pacemakers can utilize this technology.

Problems solved by DDDR mode:

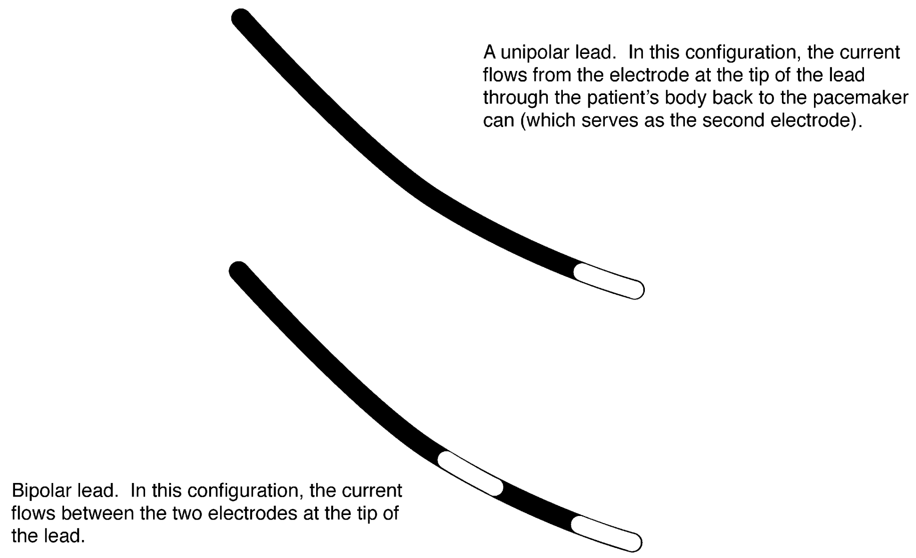
A. ~~"R on T" phenomenon~~
B. ~~Uses battery constantly~~
C. ~~Distorts all QRS complexes~~
D. ~~No AV synchrony~~
E. ~~No rate responsiveness~~

DAY 10-15

An AV sequential pacemaker, which is pacing in the atrium and tracking the patient’s native ventricular depolarization. The atrial rate of 95 is due to the rate responsive capacity of this pacemaker, which is sensing the patient’s activity and responding appropriately.



III. Pacemaker leads

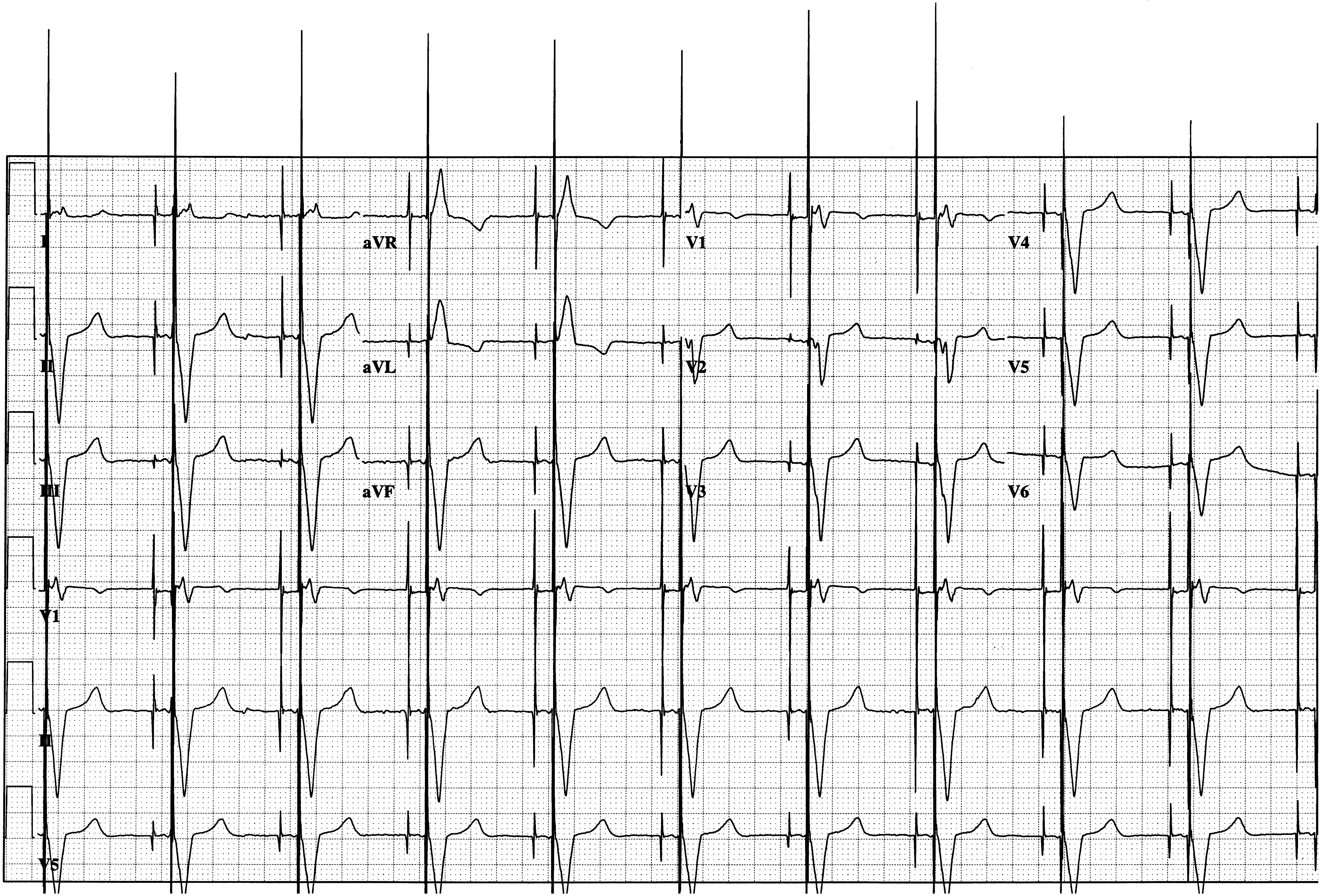


A. Unipolar leads
   1. Unipolar leads have one electrode at the tip, and the pacemaker box serves as the other electrode.
   2. The pacemaker spikes are very tall and obvious. (Day 10-16)

B. Bipolar leads
   1. Bipolar leads have one electrode at the tip of the lead and another about 1 cm proximally.
   2. Bipolar leads produce tiny spikes on the ECG that may be easily overlooked in some tracings. (Day 10-17)

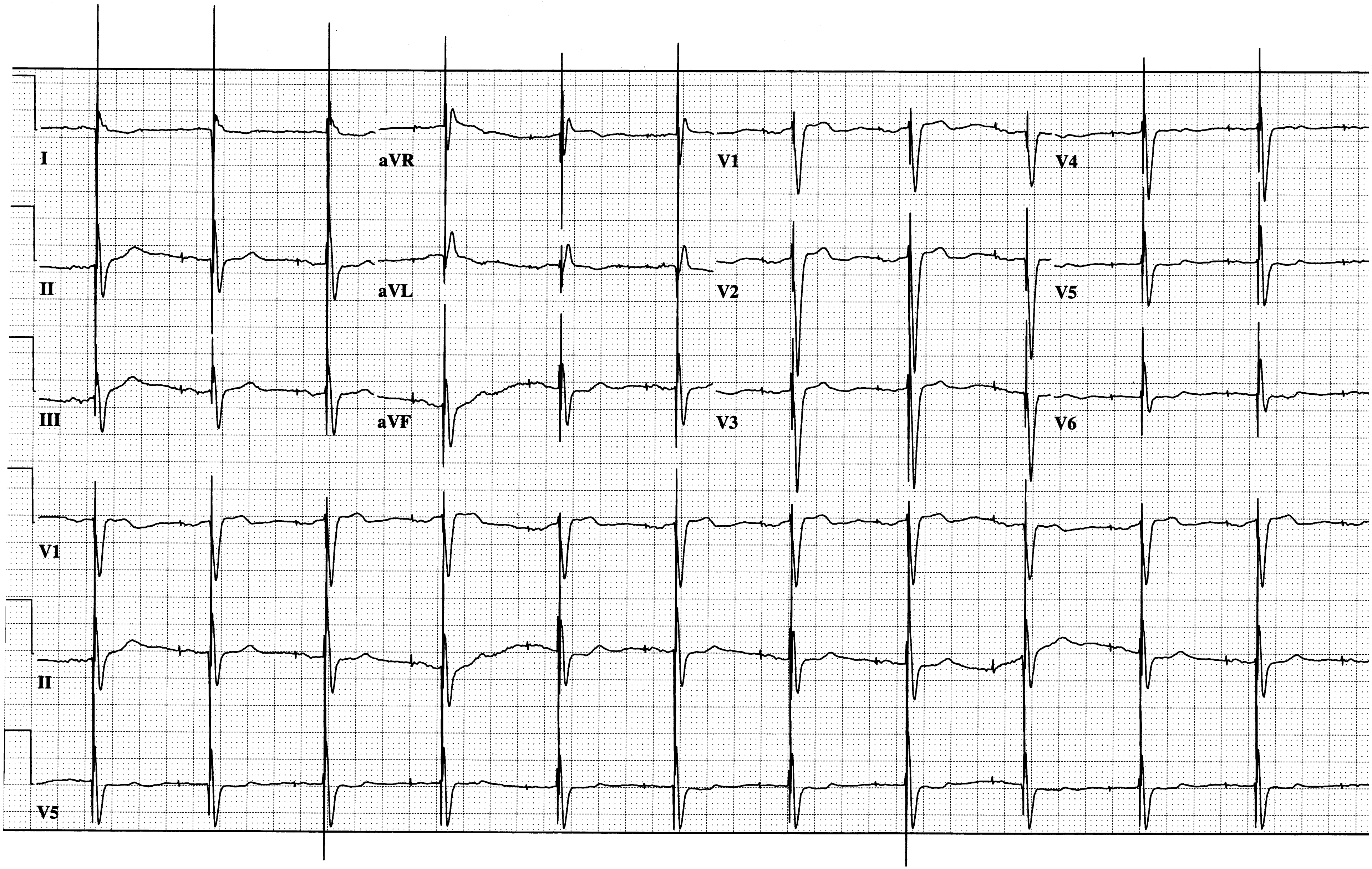
DAY 10-16

An AV sequential pacemaker with both leads programmed to the unipolar mode (note the very large pacing spikes)



DAY 10-17

An AV sequential pacemaker with the atrial lead in the bipolar mode and the ventricular lead in the unipolar mode



Sample Tracings
ECG 1

Atrial rate: ______________

Ventricular rate: ______________

Rhythm: ______________

P wave: ______________

PR interval: ______________

QRS complex:

Axis: ______________

Duration: ______________

Voltage: ______________

Morphology: ______________

ST segment: ______________

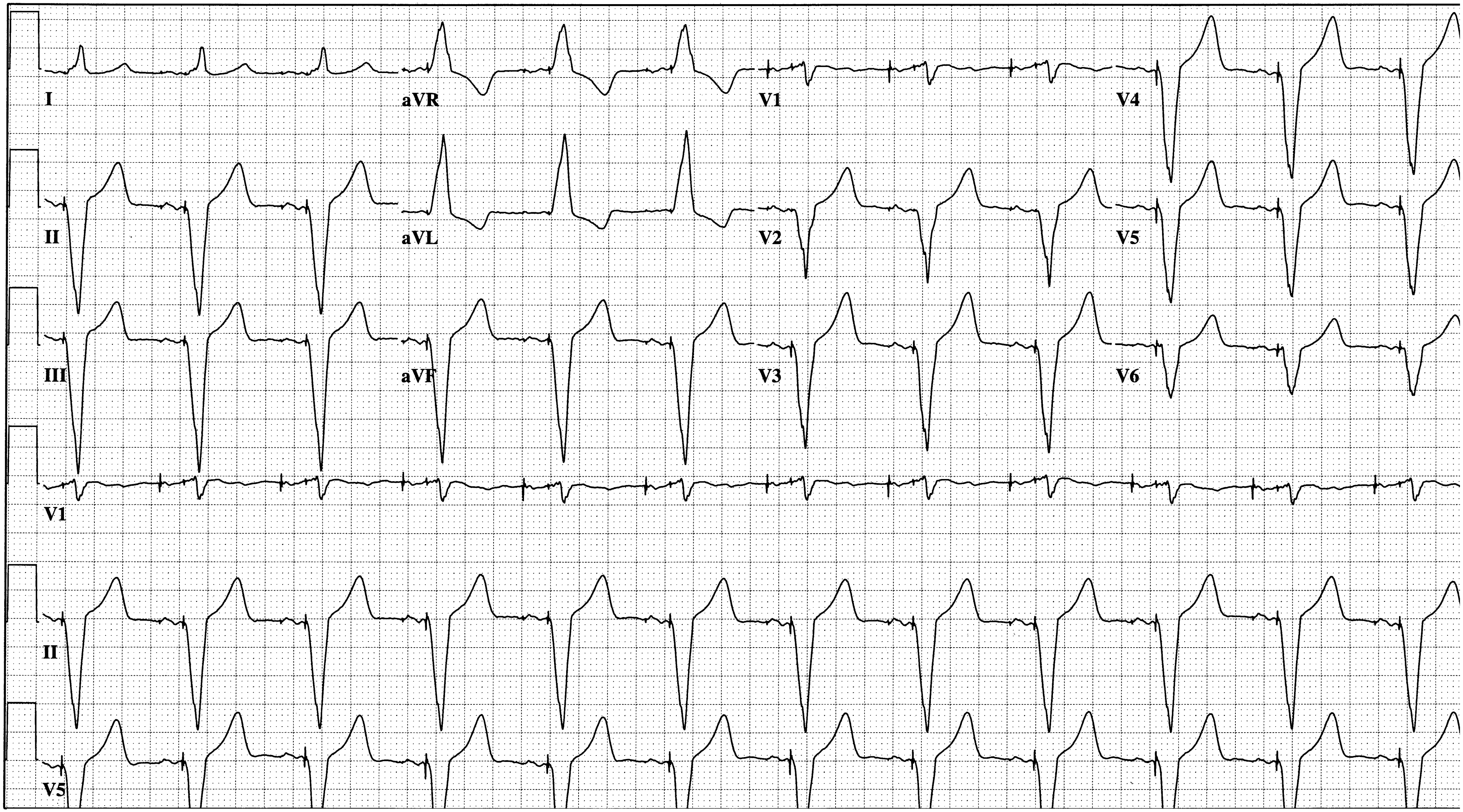
T wave: ______________

QT interval: ______________

U wave: ______________

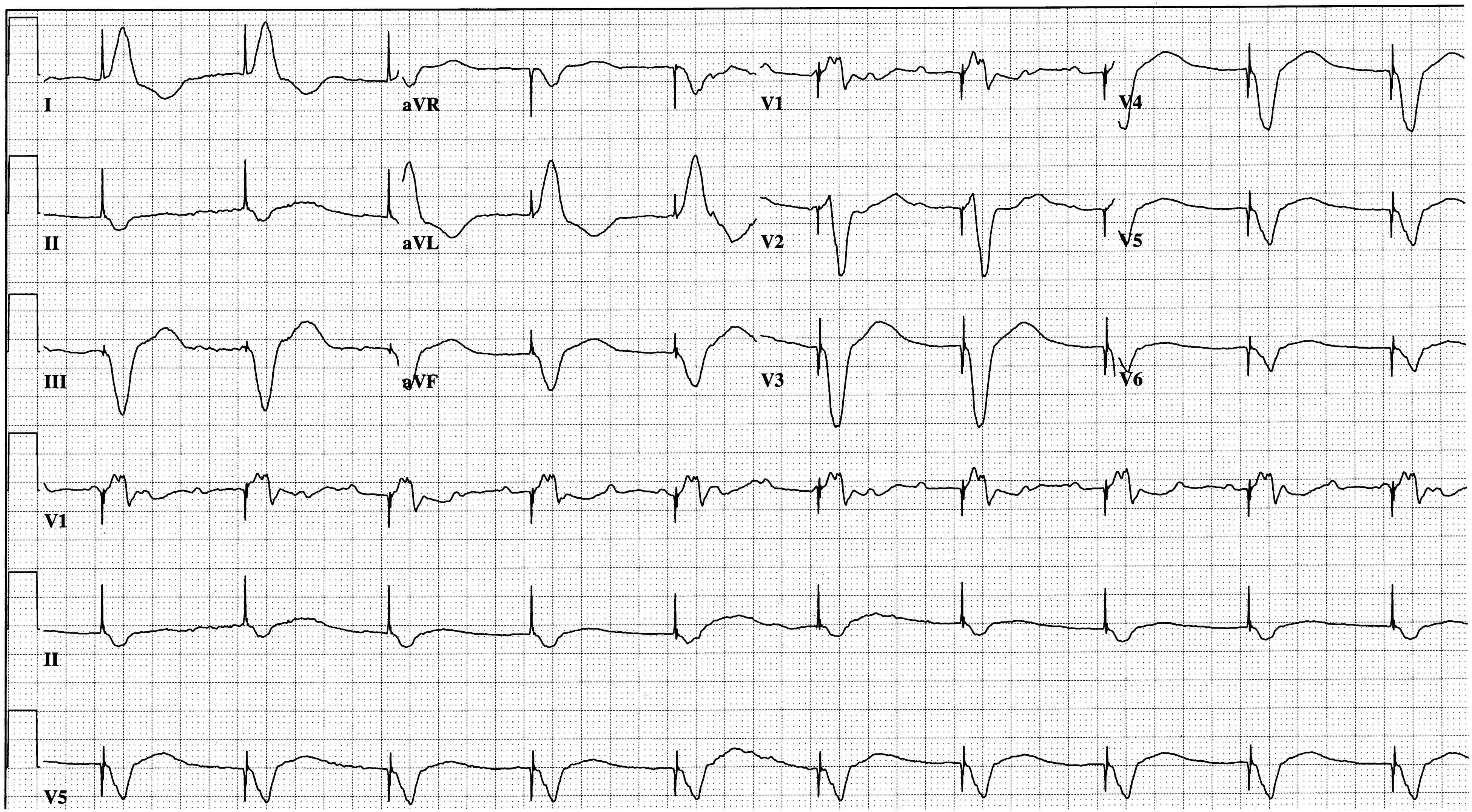
Diagnosis: ______________

____



ECG 2

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG 3

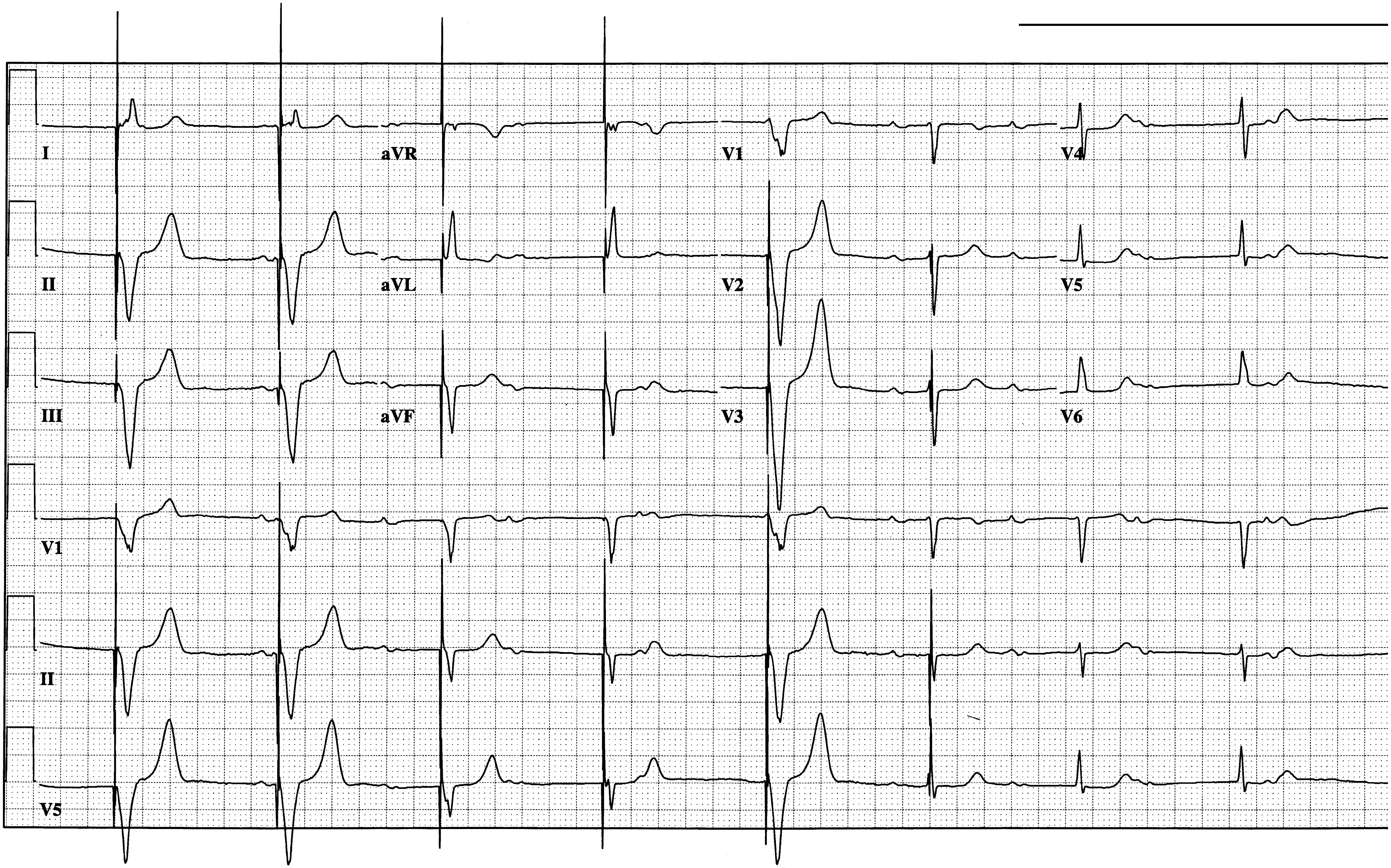
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG 4

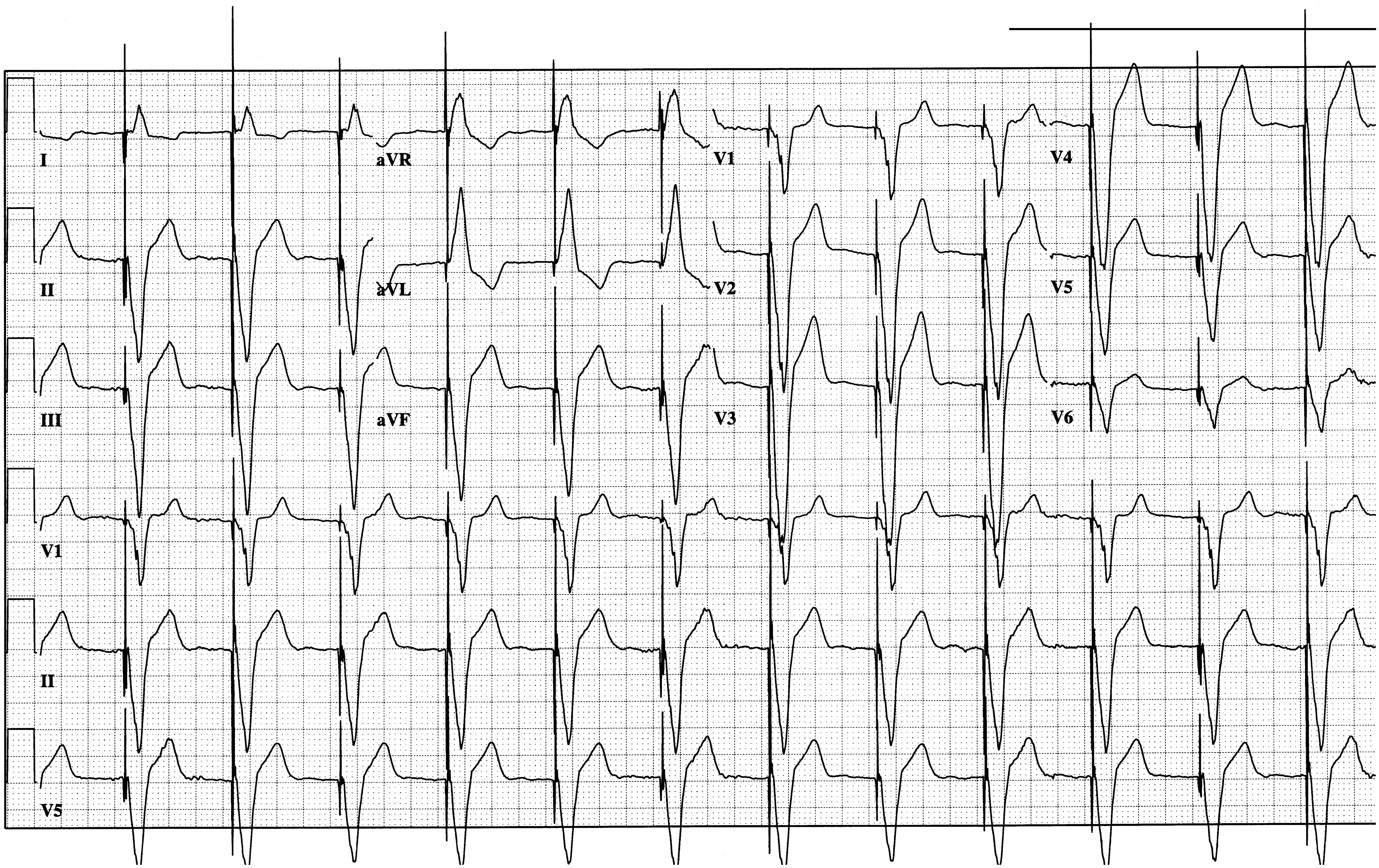
Atrial rate: ______________ QRS complex: ST segment: ______________

Ventricular rate: ______________ Axis: ______________ T wave: ______________

Rhythm: ______________ Duration: ______________ QT interval: ______________

P wave: ______________ Voltage: ______________ U wave: ______________

PR interval: ______________ Morphology: ______________ Diagnosis: ______________



ECG 5

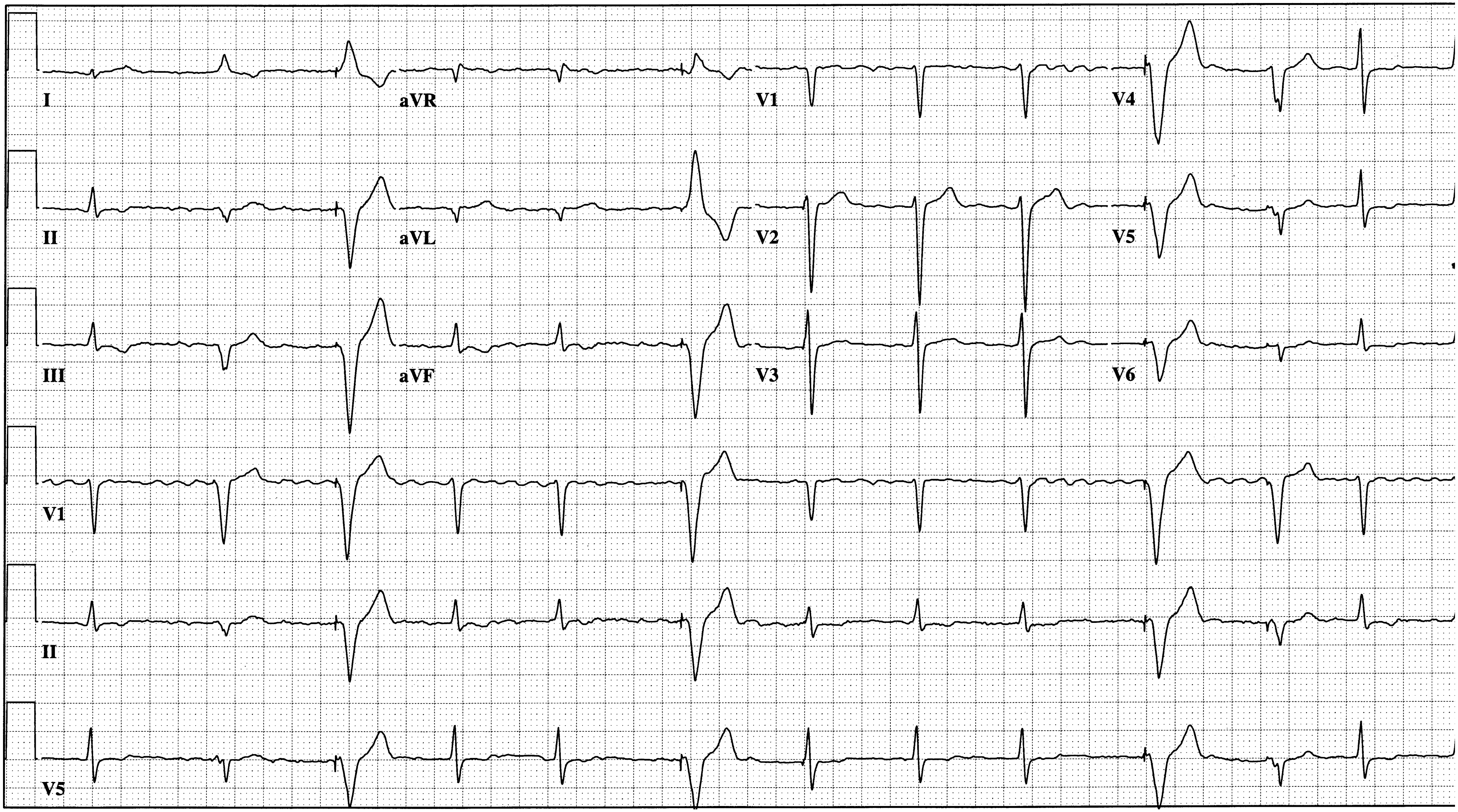
Atrial rate: ____________ QRS complex: ST segment: ____________

Ventricular rate: ____________ Axis: ____________ T wave: ____________

Rhythm: ____________ Duration: ____________ QT interval: ____________

P wave: ____________ Voltage: ____________ U wave: ____________

PR interval: ____________ Morphology: ____________ Diagnosis: ____________



ECG 6

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

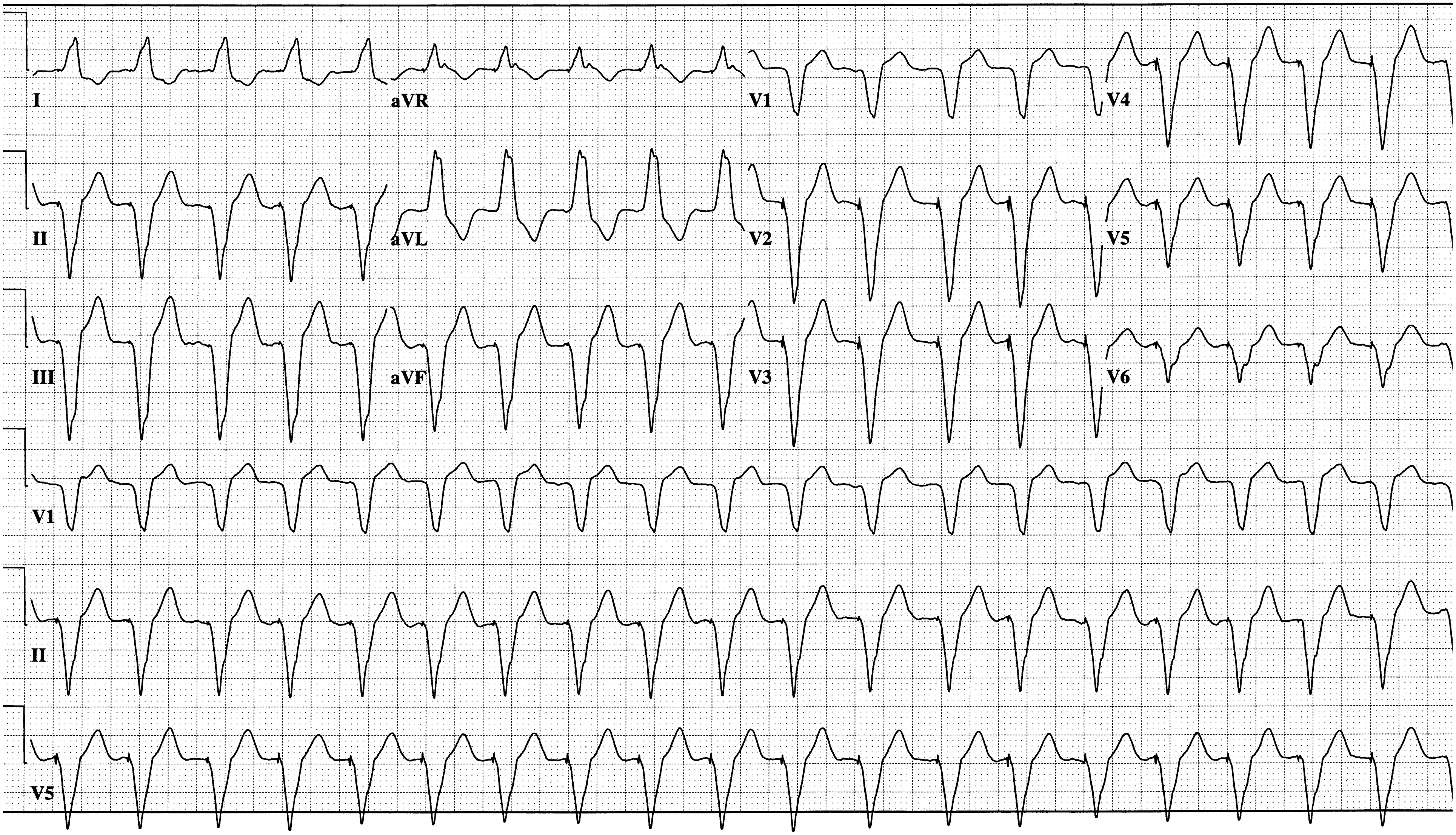
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 7

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

ST segment: ____________________

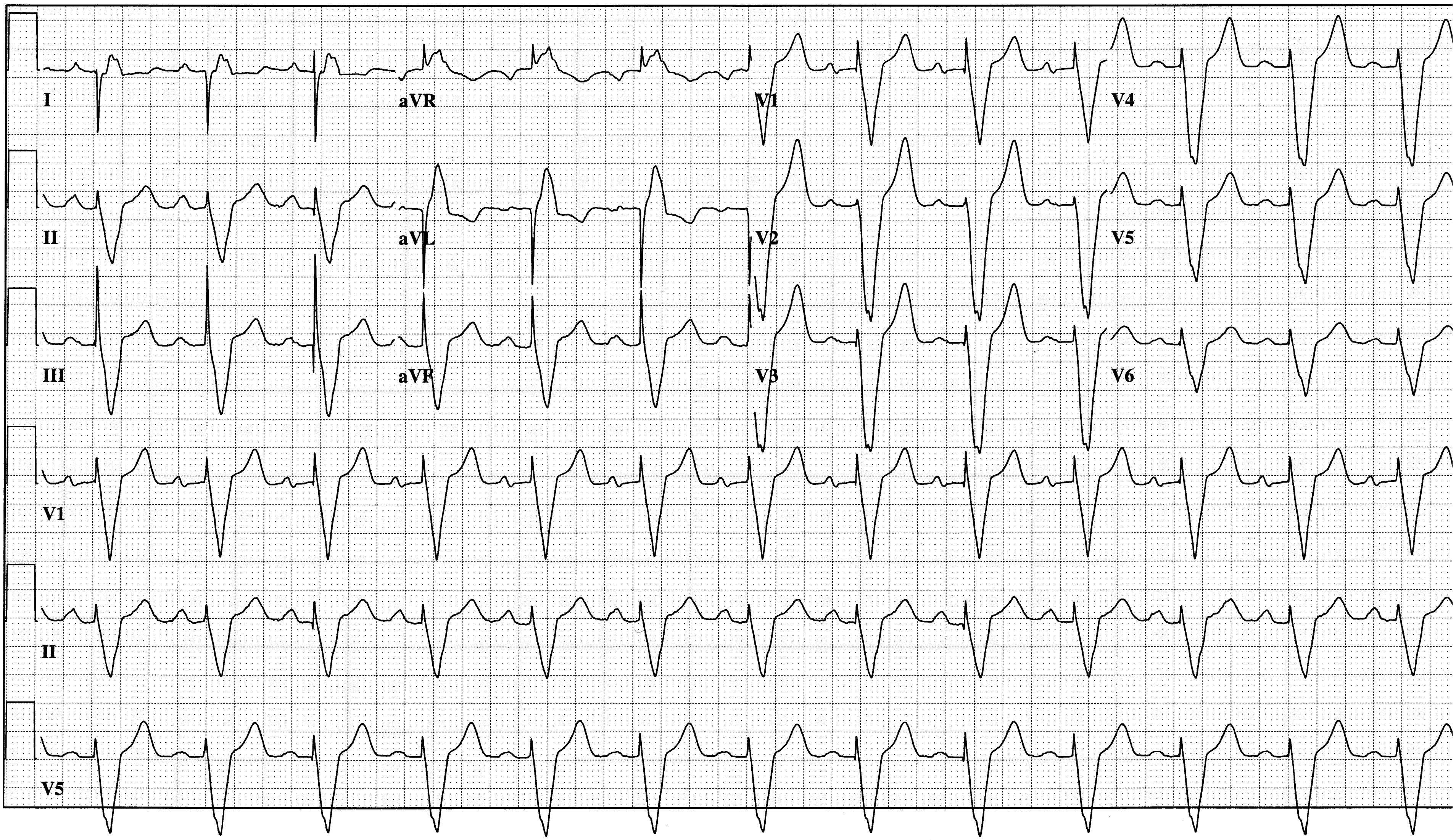
T wave: ____________________

QT interval: ____________________

U wave: ____________________

Diagnosis: ____________________

____



ECG 8

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

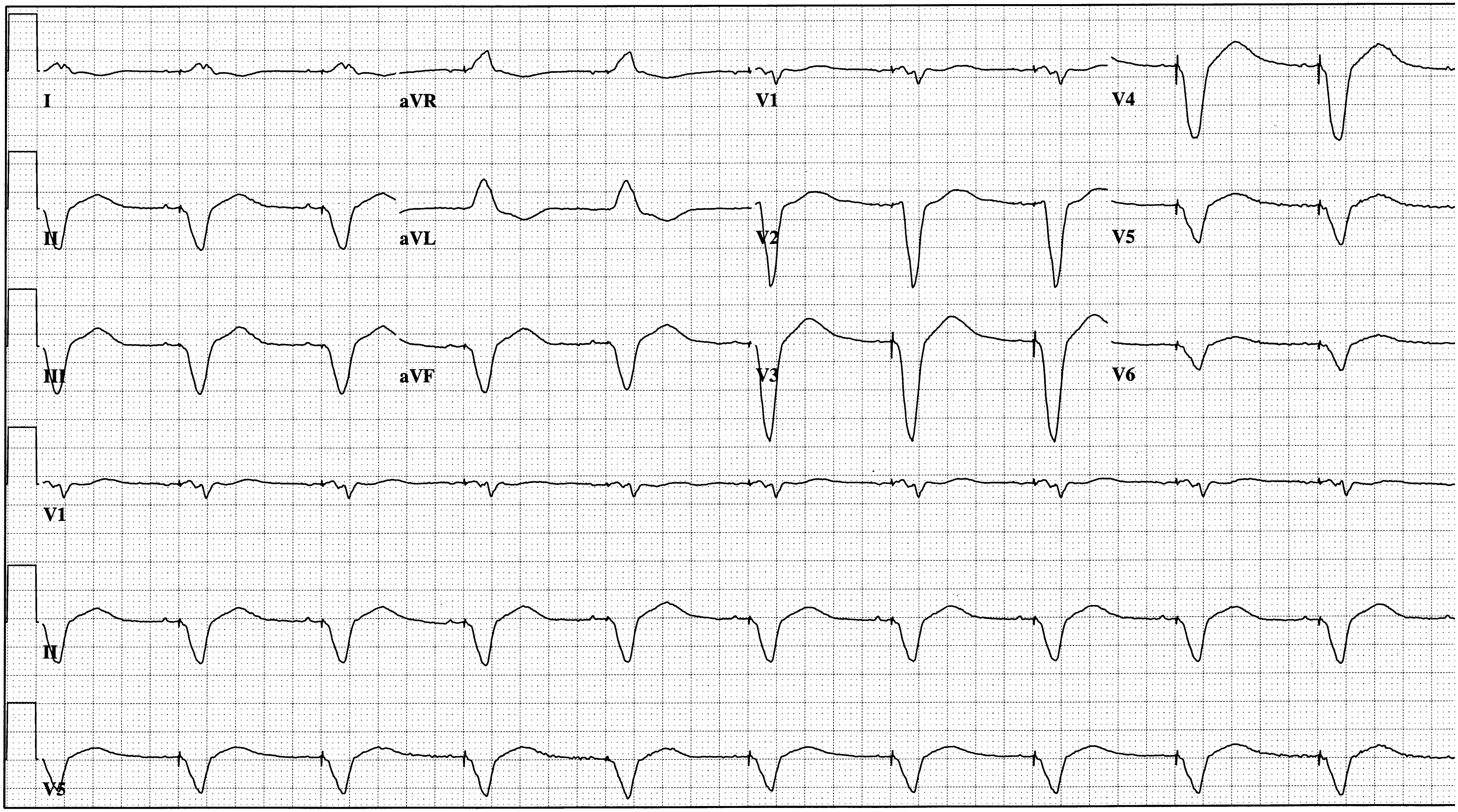
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG 9

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

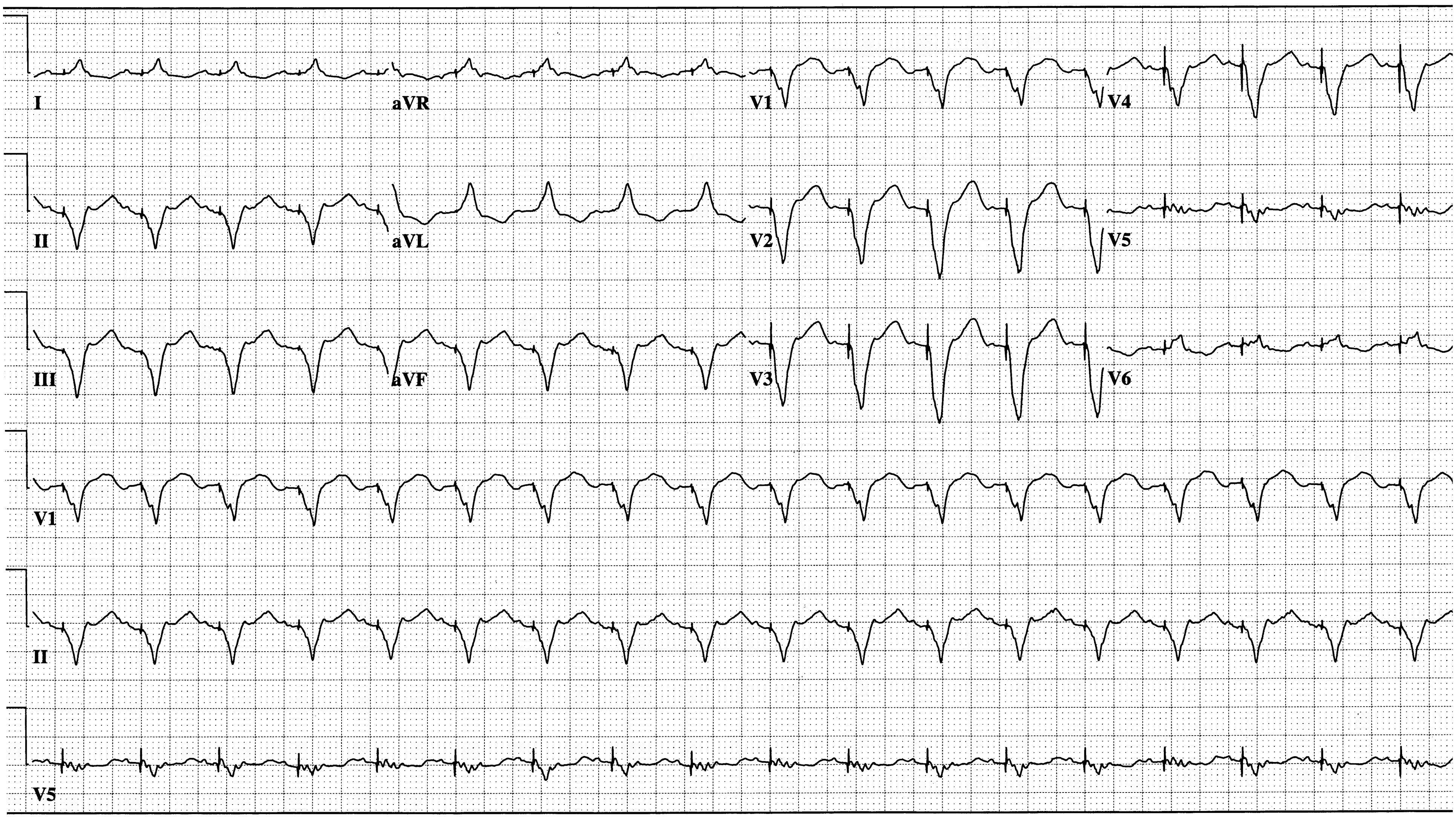
T wave: ______________________

QT interval: ______________________

U wave: ______________________

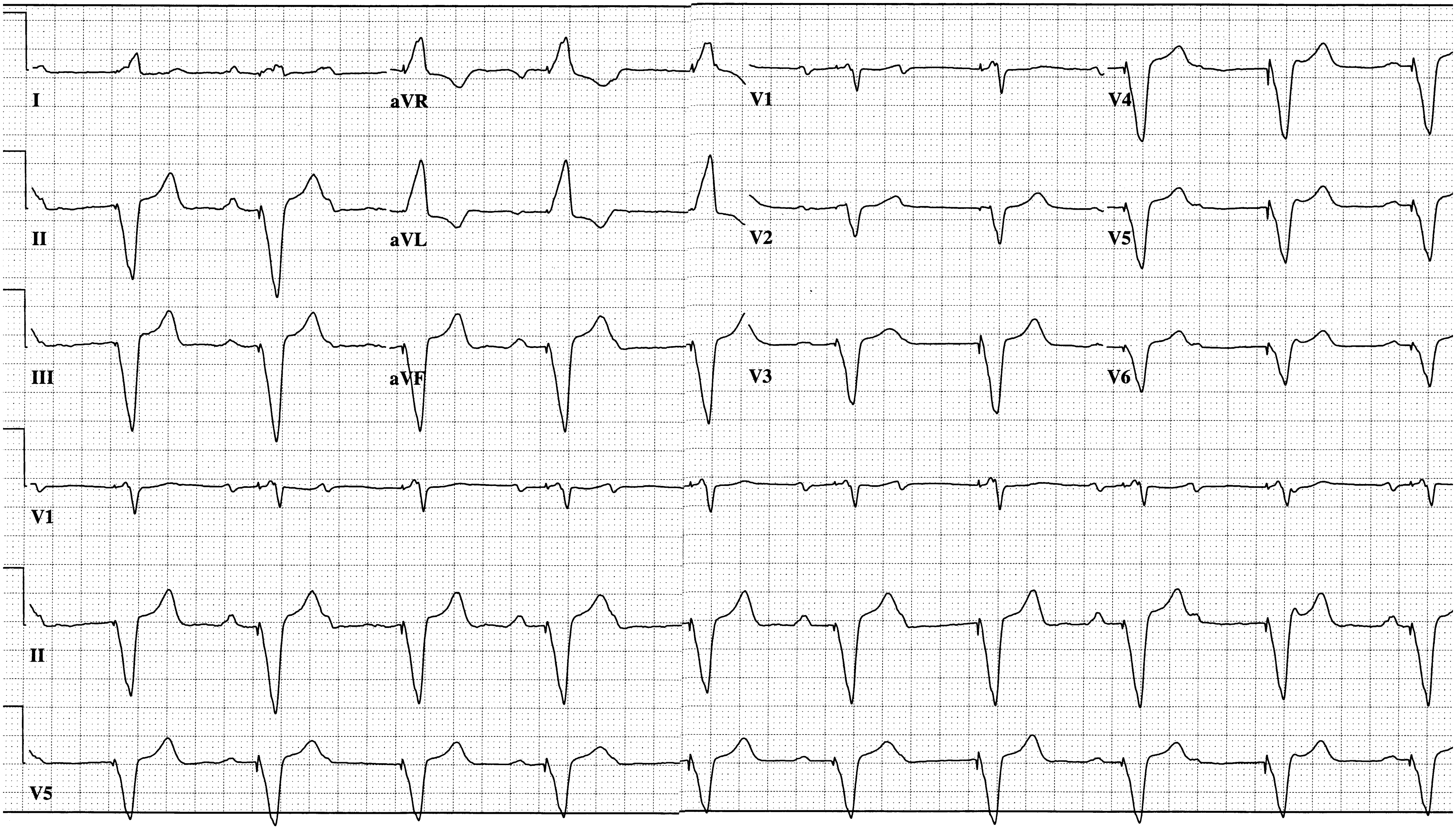
Diagnosis: ______________________

____



ECG 10

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



Electronic Pacemakers

Interpretations of Sample Tracings

ECG 1

Atrial rate: 70
Ventricular rate: 70
Rhythm: AV sequential pacing
P wave:
PR interval:
QRS complex:
  Axis:
  Duration:
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval:
U wave:
Diagnosis: AV sequential pacemaker

ECG 2

Atrial rate: 160
Ventricular rate: 60
Rhythm: Atrial tachycardia with complete heart block and a ventricular pacemaker
P wave:
PR interval:
QRS complex:
  Axis:
  Duration:
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval:
U wave:
Diagnosis: Atrial tachycardia, best seen in V_1, with complete heart block and a ventricular pacemaker

ECG 3

Atrial rate: 65
Ventricular rate: 50
Rhythm: Sinus rhythm with complete heart block and a VVI pacemaker
P wave: Normal

PR interval:
QRS complex:
  Axis: –60°
  Duration: 90 msec
  Voltage: Normal
  Morphology:
ST segment: Nonspecific changes
T wave: Normal
QT interval: 380 msec
U wave:
Diagnosis: Sinus rhythm with complete heart block and a junctional escape alternating with a VVI pacemaker. There is appropriate capture and sensing of the ventricular pacemaker. The pacemaker lead is unipolar, based upon the very tall pacemaker spikes.

ECG 4

Atrial rate:
Ventricular rate: 75
Rhythm: Atrial fibrillation with a ventricular pacemaker
P wave:
PR interval:
QRS complex:
  Axis:
  Duration:
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval:
U wave:
Diagnosis: Atrial fibrillation with a ventricular pacemaker. The pacemaker lead is unipolar, based upon the very tall pacemaker spikes.

ECG 5

Atrial rate:
Ventricular rate: 74
Rhythm: Atrial fibrillation with a ventricular pacemaker
P wave:
PR interval:
QRS complex:
  Axis: 75°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Nonspecific changes

T wave: Nonspecific changes
QT interval: 240 msec
U wave:
Diagnosis: Atrial fibrillation with a VVI pacemaker. There is appropriate capture and sensing of the ventricular pacemaker. The pacemaker lead is bipolar, based upon the tiny pacemaker spikes.

ECG 6

Atrial rate:
Ventricular rate: 120
Rhythm: Ventricular pacing possibly representing pacemaker mediated tachycardia
P wave:
PR interval:
QRS complex:
  Axis:
  Duration:
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval:
U wave:
Diagnosis: Possible pacemaker mediated tachycardia. This term is used to describe a situation in which a retrograde P wave following a paced ventricular beat is sensed by an AV sequential pacemaker. The pacemaker then waits the programmed AV delay and paces the ventricle again, setting up a “reentry” arrhythmia in which the pacemaker serves as part of the loop. The evidence for this diagnosis includes a rapidly paced ventricular rhythm at the programmed upper rate limit in a patient known to have an AV sequential pacemaker. Modern AV sequential pacemakers incorporate a programmable refractory period after a paced ventricular beat during which it will not respond to atrial activity, so this situation is now infrequently encountered. The application of an external magnet to the pacemaker will inhibit the sensing circuitry and force the pacemaker to pace in its AV sequential mode at its base rate (i.e., DOO), and stop the arrhythmia. With modern pacemakers, this ECG is likely to represent sinus tachycardia with appropriate tracking of the atrial rate by an AV sequential pacemaker or a ventricular pacemaker with rate responsiveness. Electronic interrogation of the pacemaker would establish the mode of activity in all cases.

ECG 7

Atrial rate: 80
Ventricular rate: 80
Rhythm: Sinus rhythm with a ventricular pacemaker
P wave: Normal
PR interval:

QRS complex:
Axis:
Duration:
Voltage:
Morphology:
ST segment:
T wave:
QT interval:
U wave:
Diagnosis: Sinus rhythm with sensing in the atrium and pacing in the ventricle

ECG 8

Atrial rate: 60
Ventricular rate: 60
Rhythm: Sinus rhythm with a ventricular pacemaker
P wave: Normal
PR interval:
QRS complex:
Axis:
Duration:
Voltage:
Morphology:
ST segment:
T wave:
QT interval:
U wave:
Diagnosis: Sinus rhythm with sensing in the atrium and pacing in the ventricle

ECG 9

Atrial rate: 110
Ventricular rate: 110
Rhythm: Sinus tachycardia with a ventricular pacemaker
P wave: Normal
PR interval:
QRS complex:
Axis:
Duration:
Voltage:
Morphology:
ST segment:
T wave:
QT interval:
U wave:
Diagnosis: Sinus tachycardia with sensing in the atrium and pacing in the ventricle

ECG 10

Atrial rate: 95
Ventricular rate: 59
Rhythm: Sinus rhythm with complete heart block and a ventricular pacemaker
P wave:
PR interval:
QRS complex:
  Axis:
  Duration:
  Voltage:
  Morphology:
  ST segment:
  T wave:
  QT interval:
  U wave:
  Diagnosis: Sinus rhythm with complete heart block with a ventricular pacemaker

Sample Tracings
ECG Review 01

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

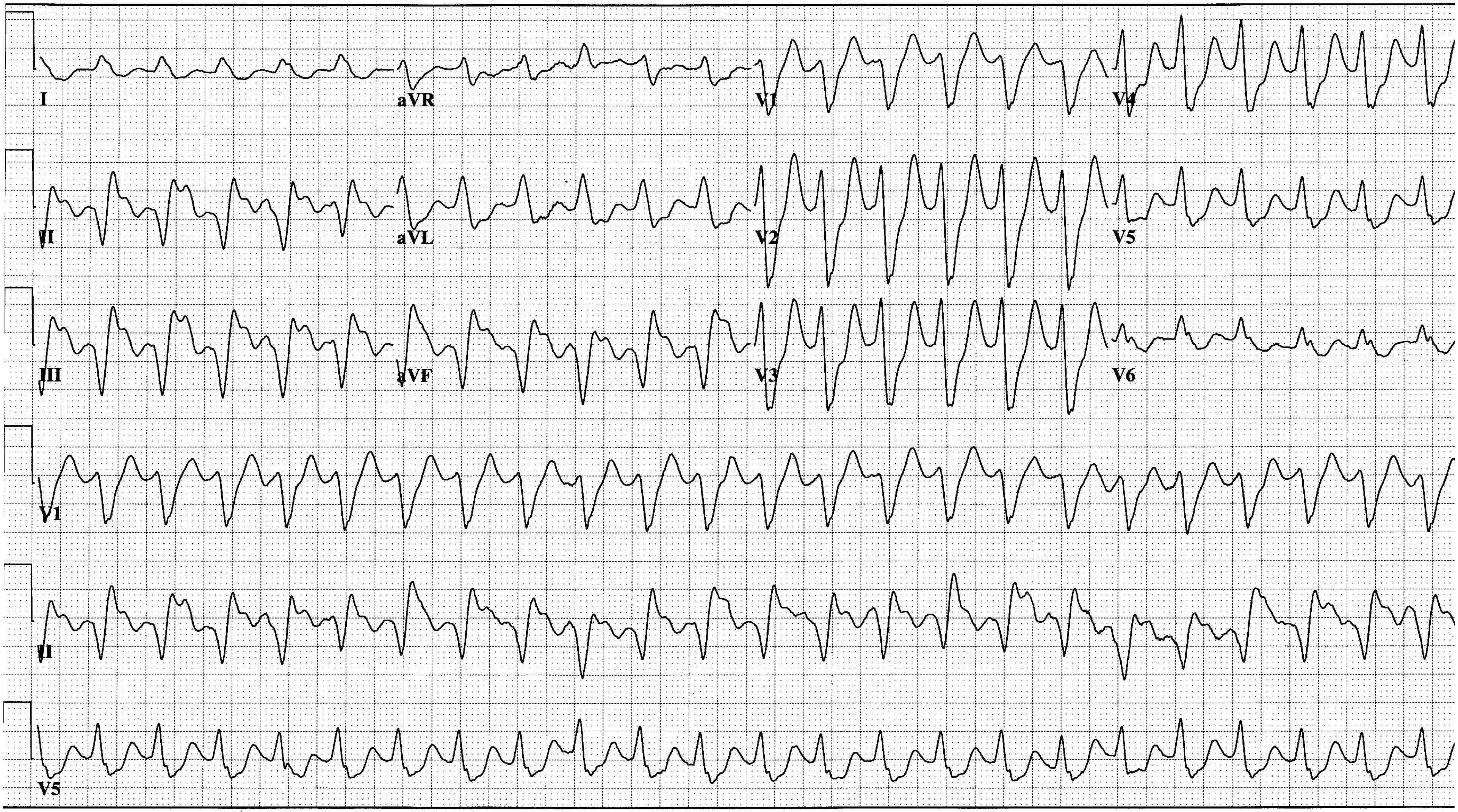
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG Review 02

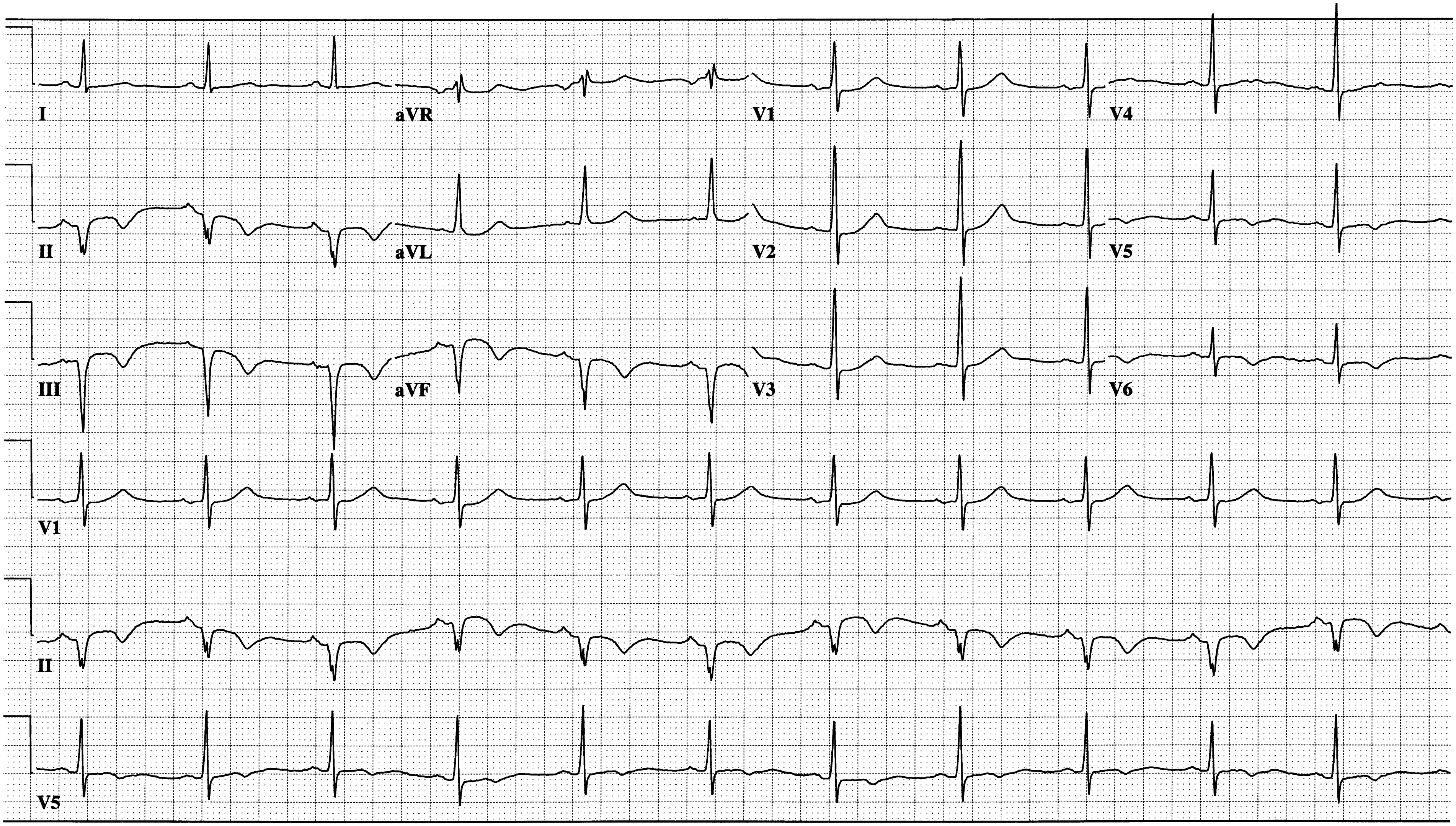
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG Review 03

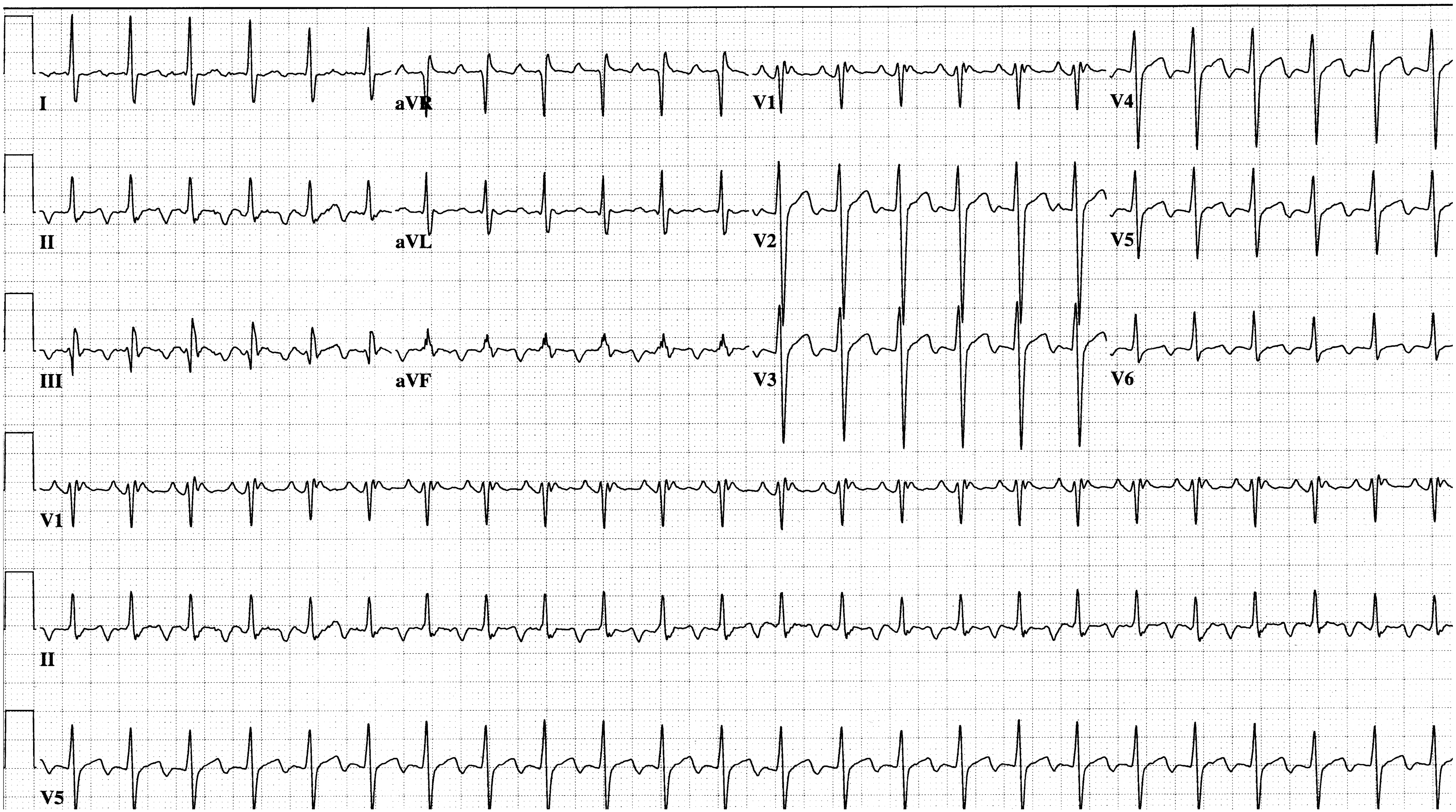
Atrial rate: ______________________
QRS complex:
ST segment: ______________________

Ventricular rate: ______________________
Axis: ______________________
T wave: ______________________

Rhythm: ______________________
Duration: ______________________
QT interval: ______________________

P wave: ______________________
Voltage: ______________________
U wave: ______________________

PR interval: ______________________
Morphology: ______________________
Diagnosis: ______________________



ECG Review 04

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

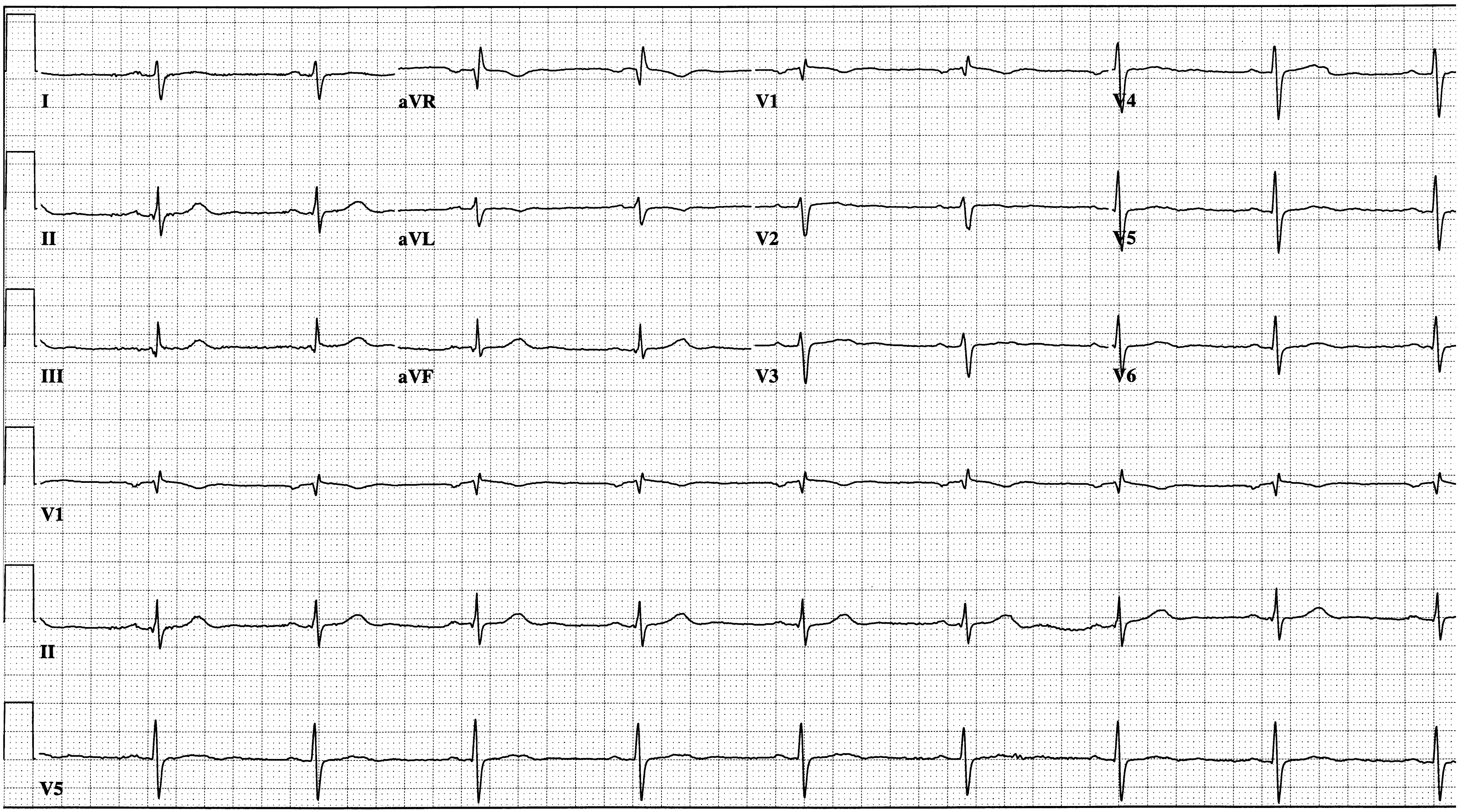
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG Review 05

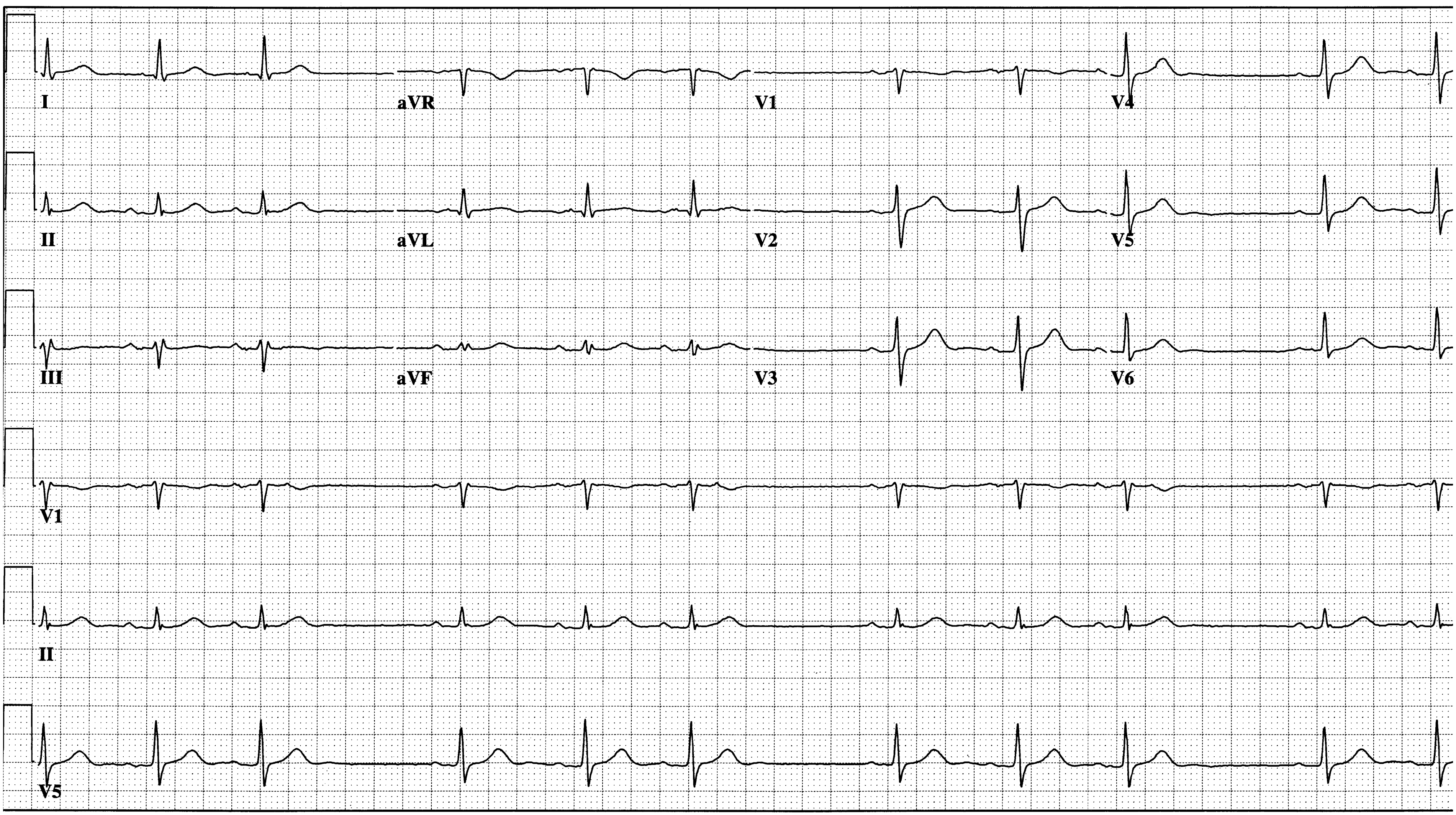
Atrial rate: ____________________ QRS complex: ST segment: ____________________

Ventricular rate: ____________________ Axis: ____________________ T wave: ____________________

Rhythm: ____________________ Duration: ____________________ QT interval: ____________________

P wave: ____________________ Voltage: ____________________ U wave: ____________________

PR interval: ____________________ Morphology: ____________________ Diagnosis: ____________________



ECG Review 06

Atrial rate: ____________

Ventricular rate: ____________

Rhythm: ____________

P wave: ____________

PR interval: ____________

QRS complex:

Axis: ____________

Duration: ____________

Voltage: ____________

Morphology: ____________

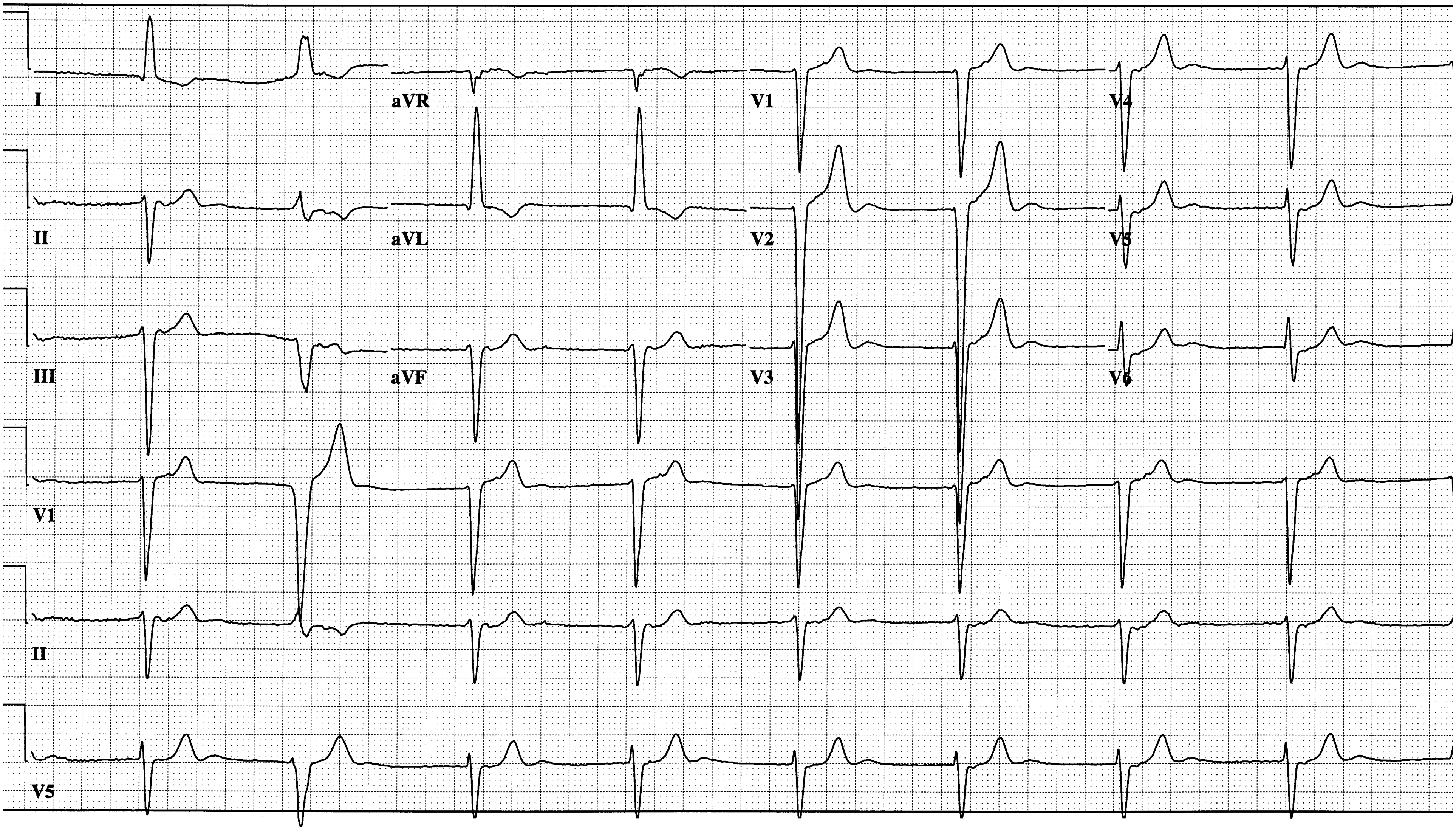
ST segment: ____________

T wave: ____________

QT interval: ____________

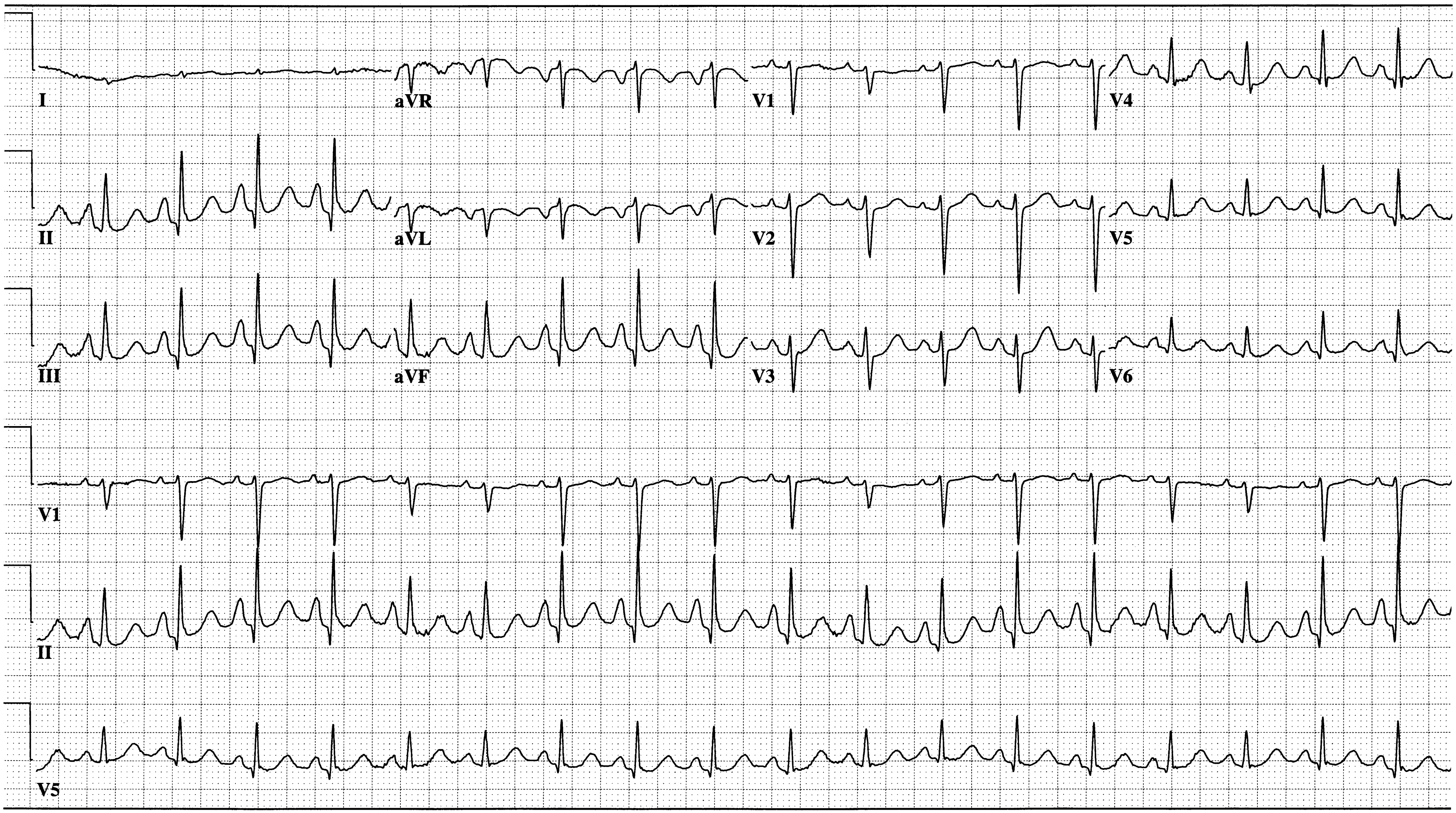
U wave: ____________

Diagnosis: ____________



ECG Review 07

Atrial rate:	QRS complex:	ST segment:
Ventricular rate:	Axis:	T wave:
Rhythm:	Duration:	QT interval:
P wave:	Voltage:	U wave:
PR interval:	Morphology:	Diagnosis:



ECG Review 08

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

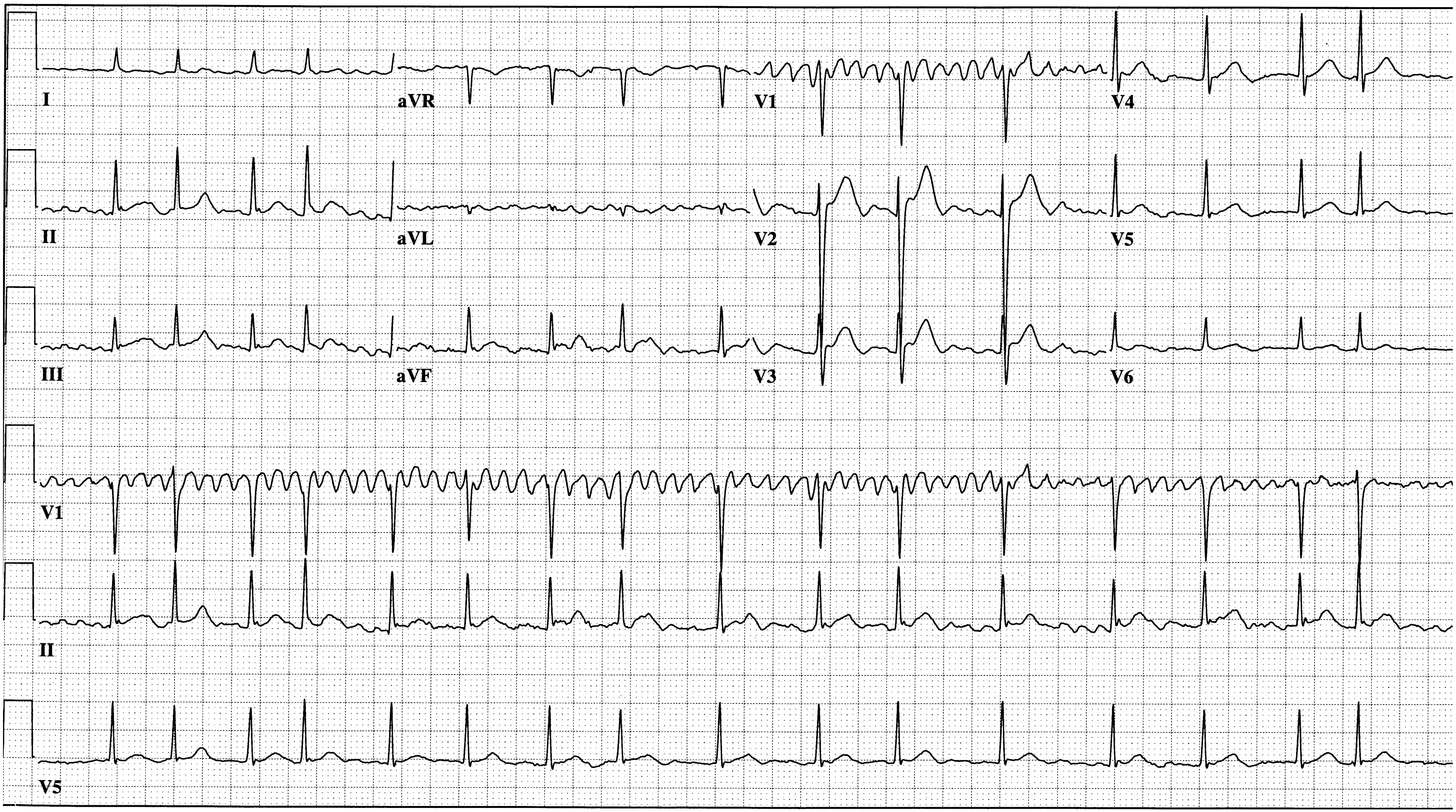
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG Review 09

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

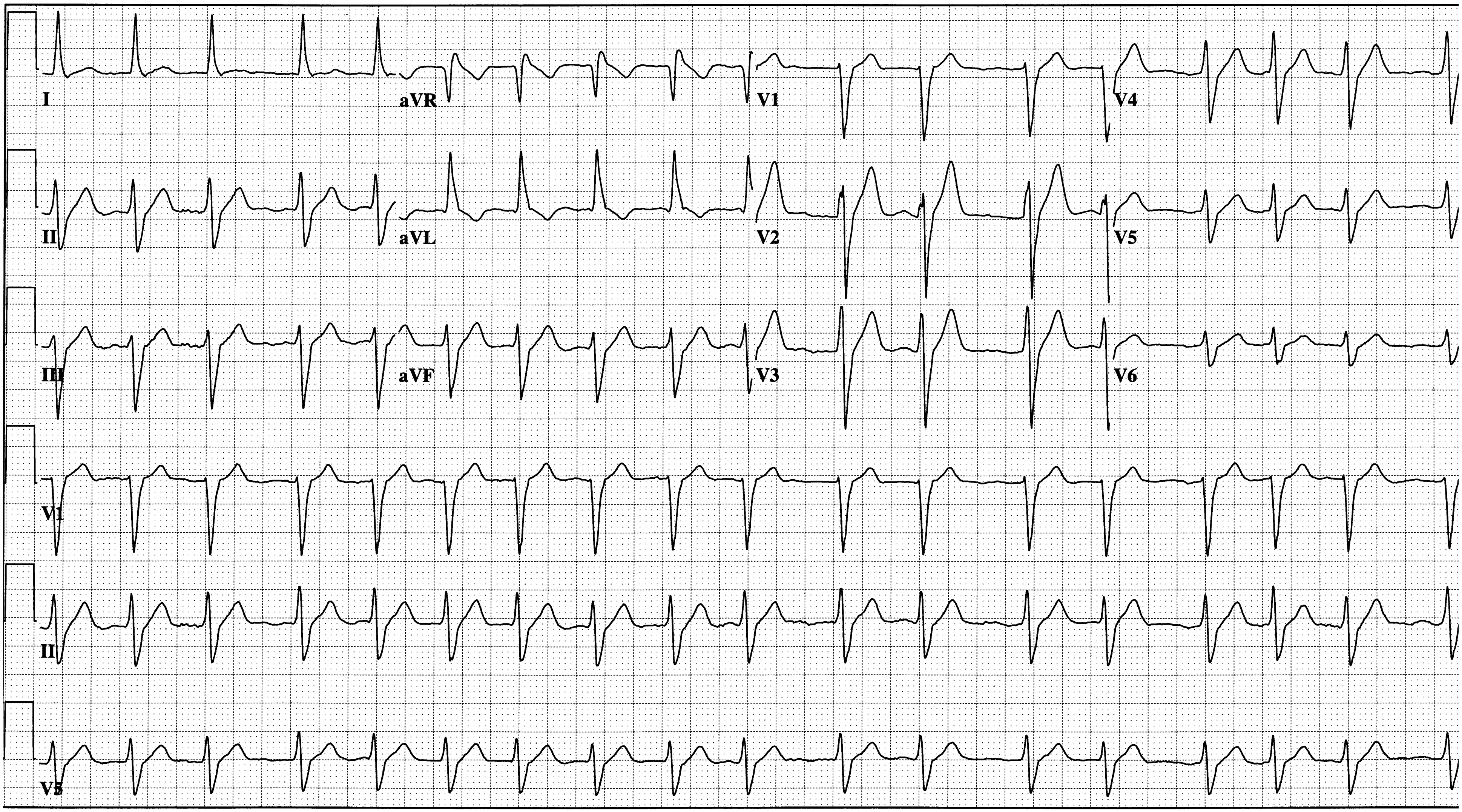
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG Review 10

Atrial rate: ____________

Ventricular rate: ____________

Rhythm: ____________

P wave: ____________

PR interval: ____________

QRS complex:

Axis: ____________

Duration: ____________

Voltage: ____________

Morphology: ____________

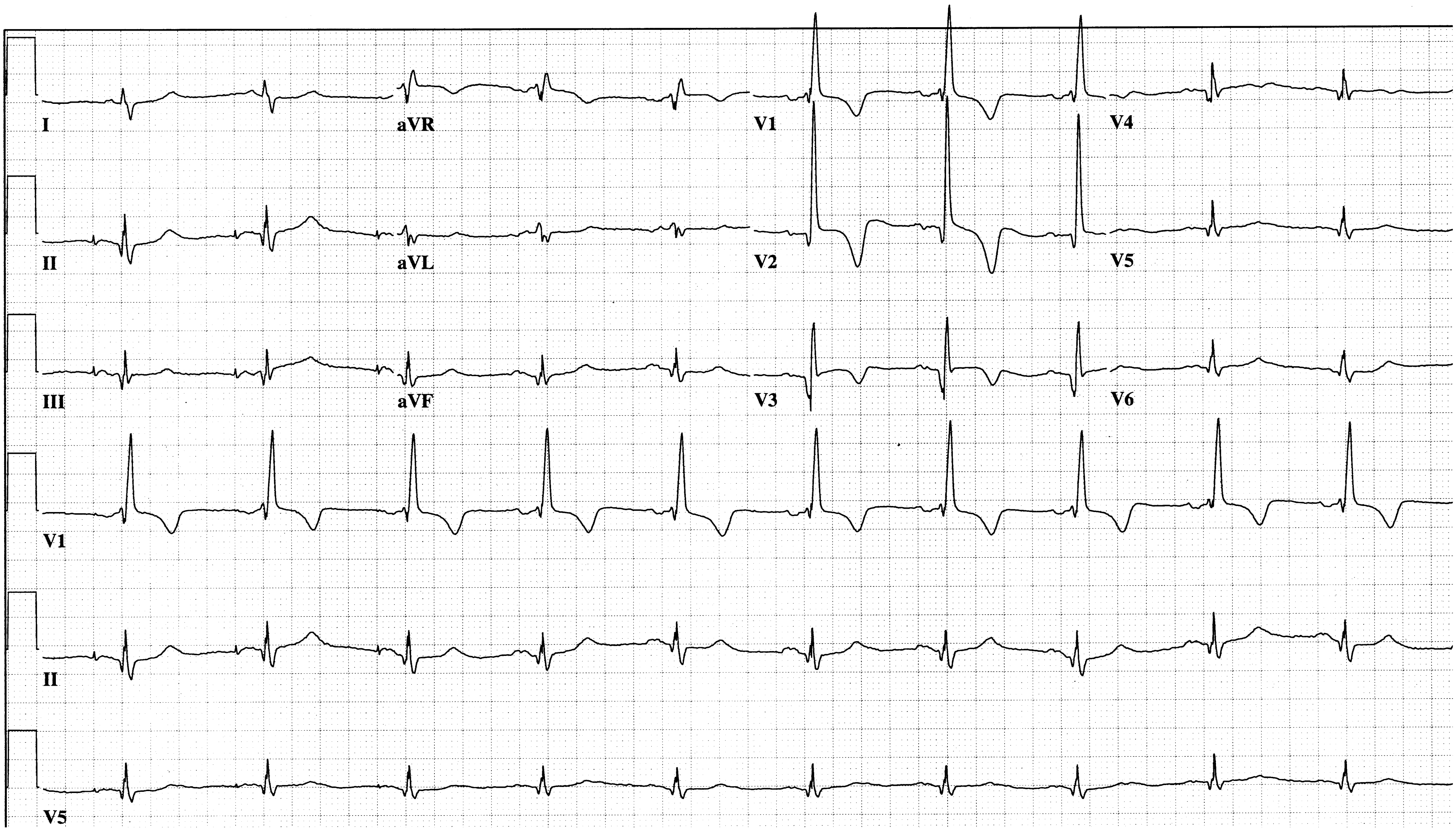
ST segment: ____________

T wave: ____________

QT interval: ____________

U wave: ____________

Diagnosis: ____________



ECG Review 11

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

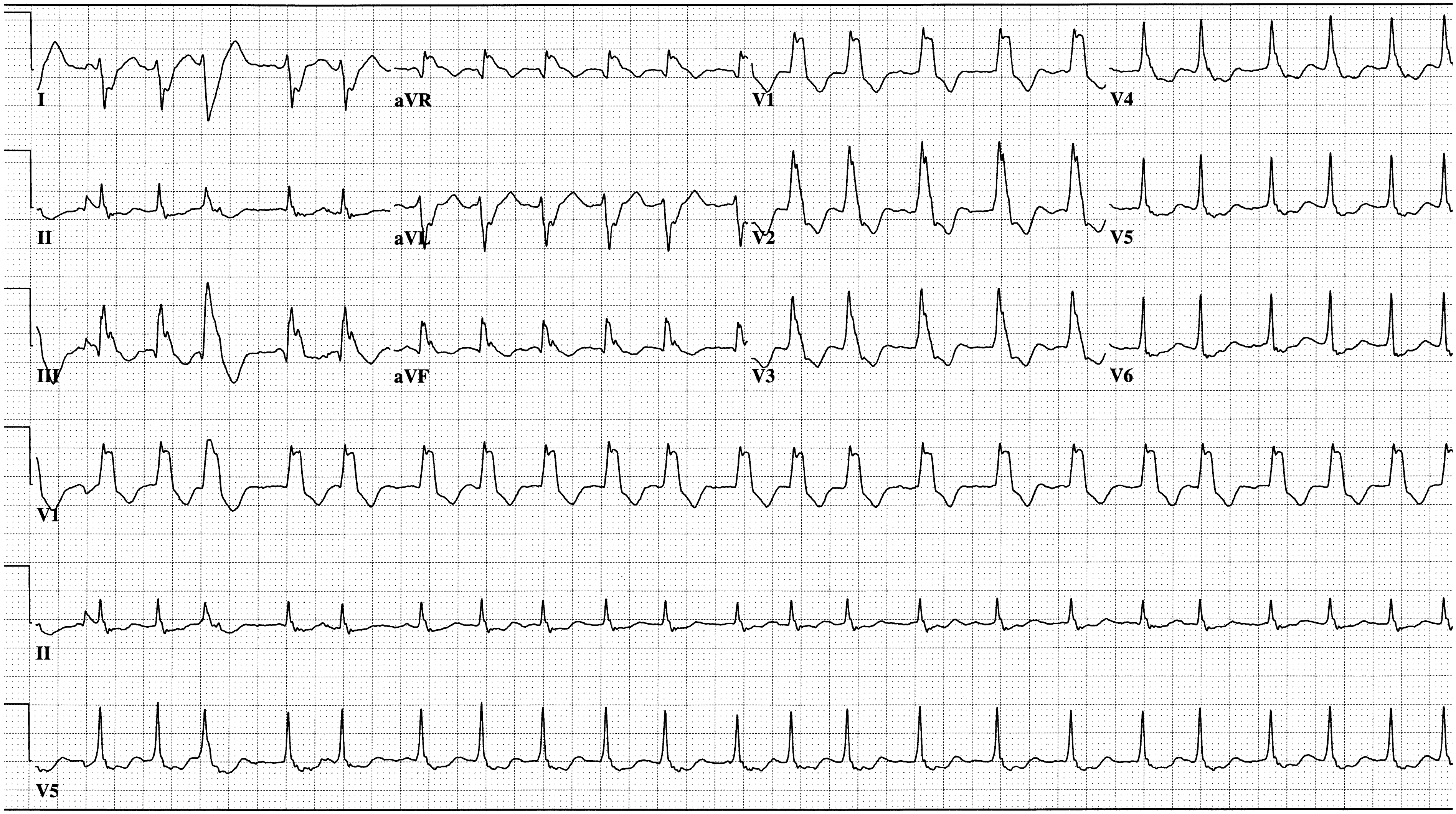
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG Review 12

Atrial rate: ______________

Ventricular rate: ______________

Rhythm: ______________

P wave: ______________

PR interval: ______________

QRS complex:

Axis: ______________

Duration: ______________

Voltage: ______________

Morphology: ______________

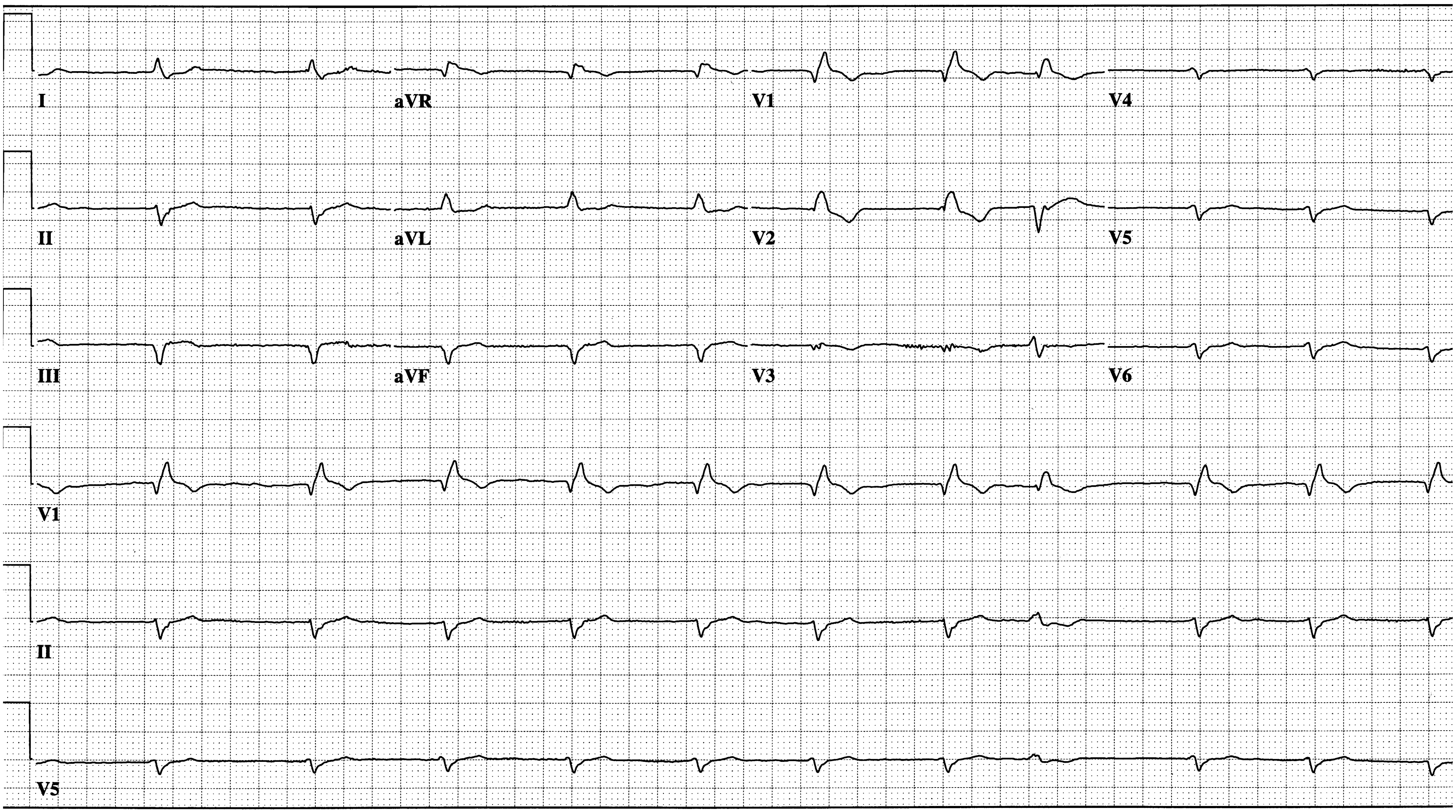
ST segment: ______________

T wave: ______________

QT interval: ______________

U wave: ______________

Diagnosis: ______________



ECG Review 13

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

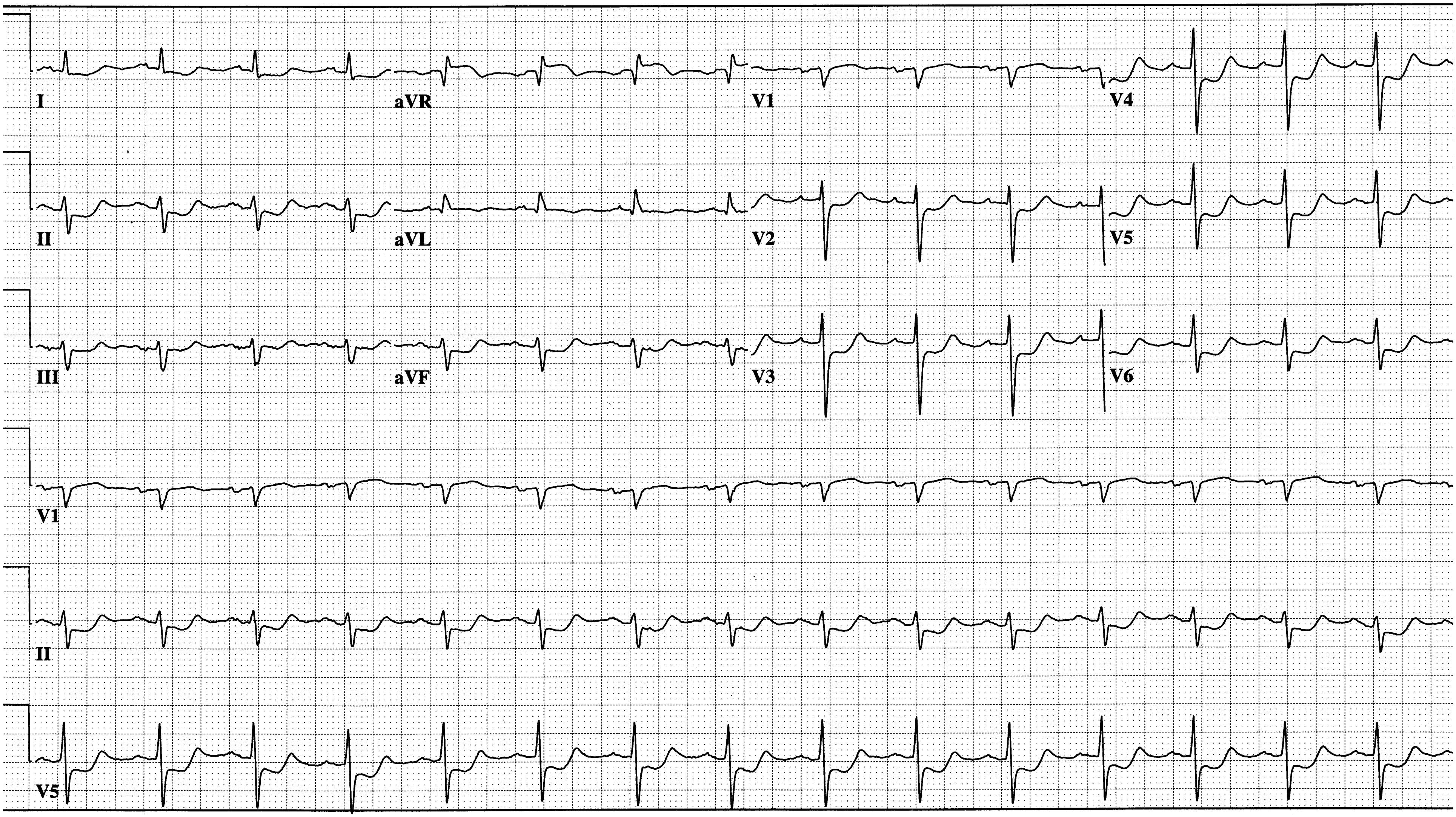
T wave: ______________________

QT interval: ______________________

U wave: ______________________

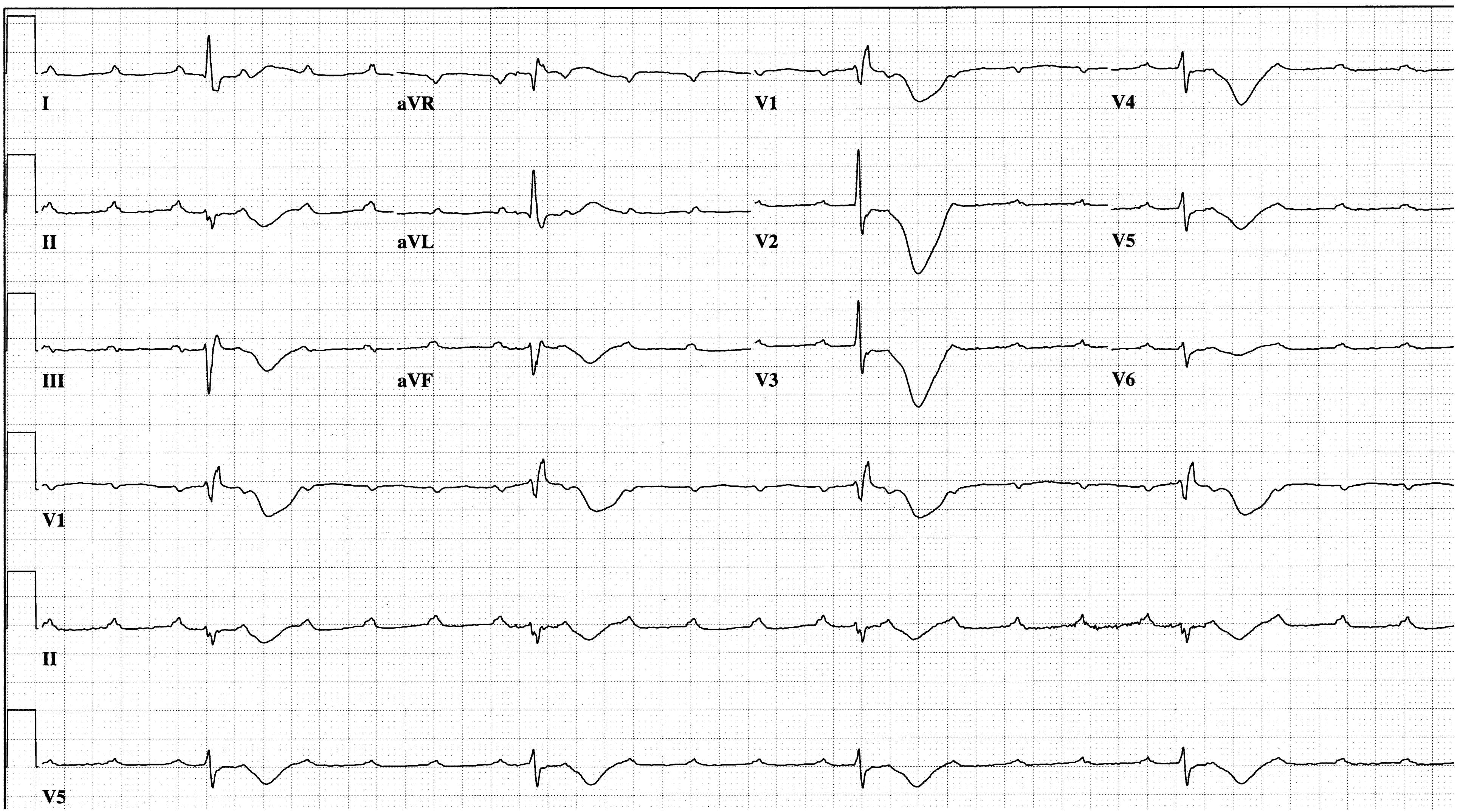
Diagnosis: ______________________

____



ECG Review 14

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG Review 15

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

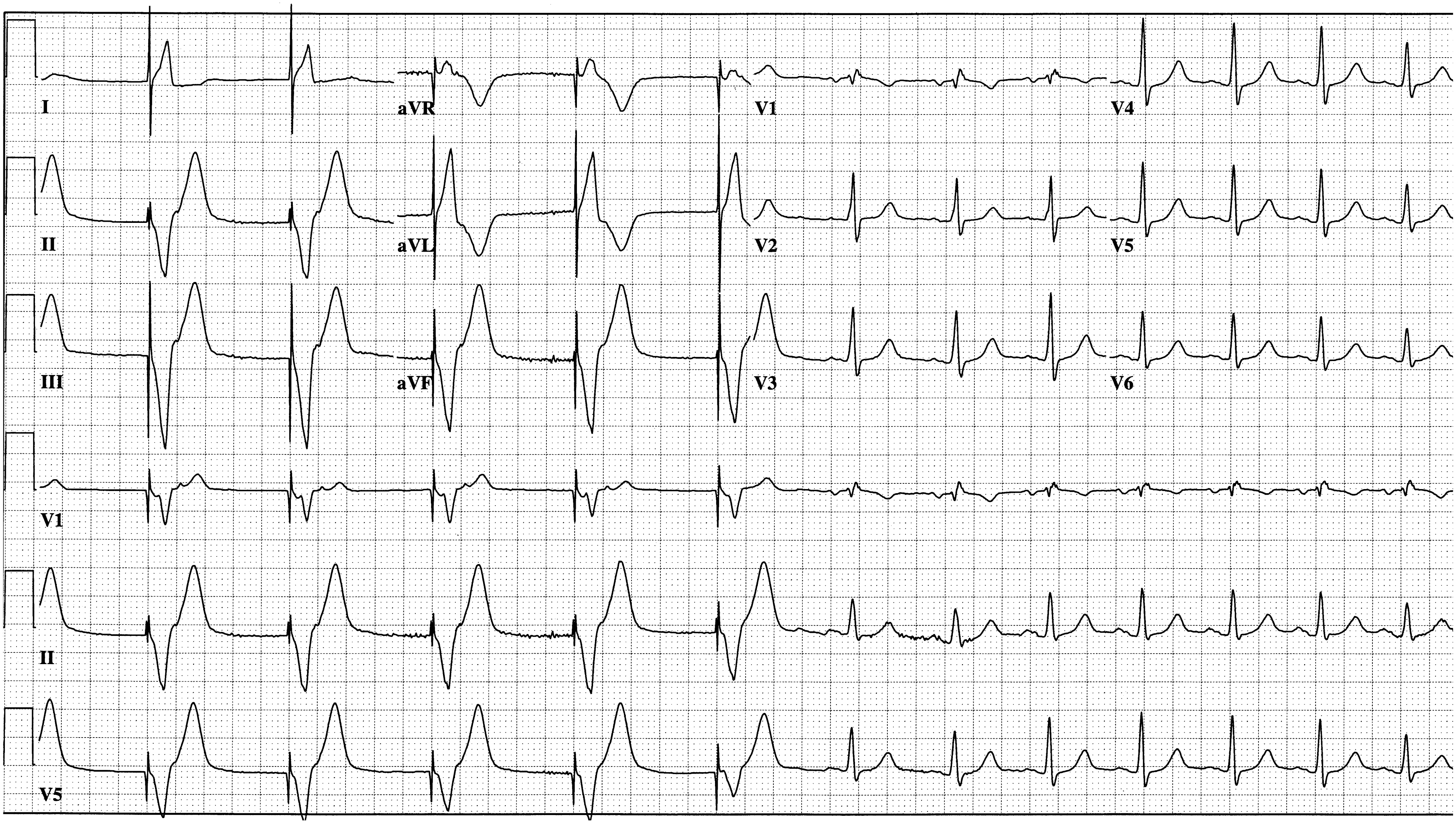
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG Review 16

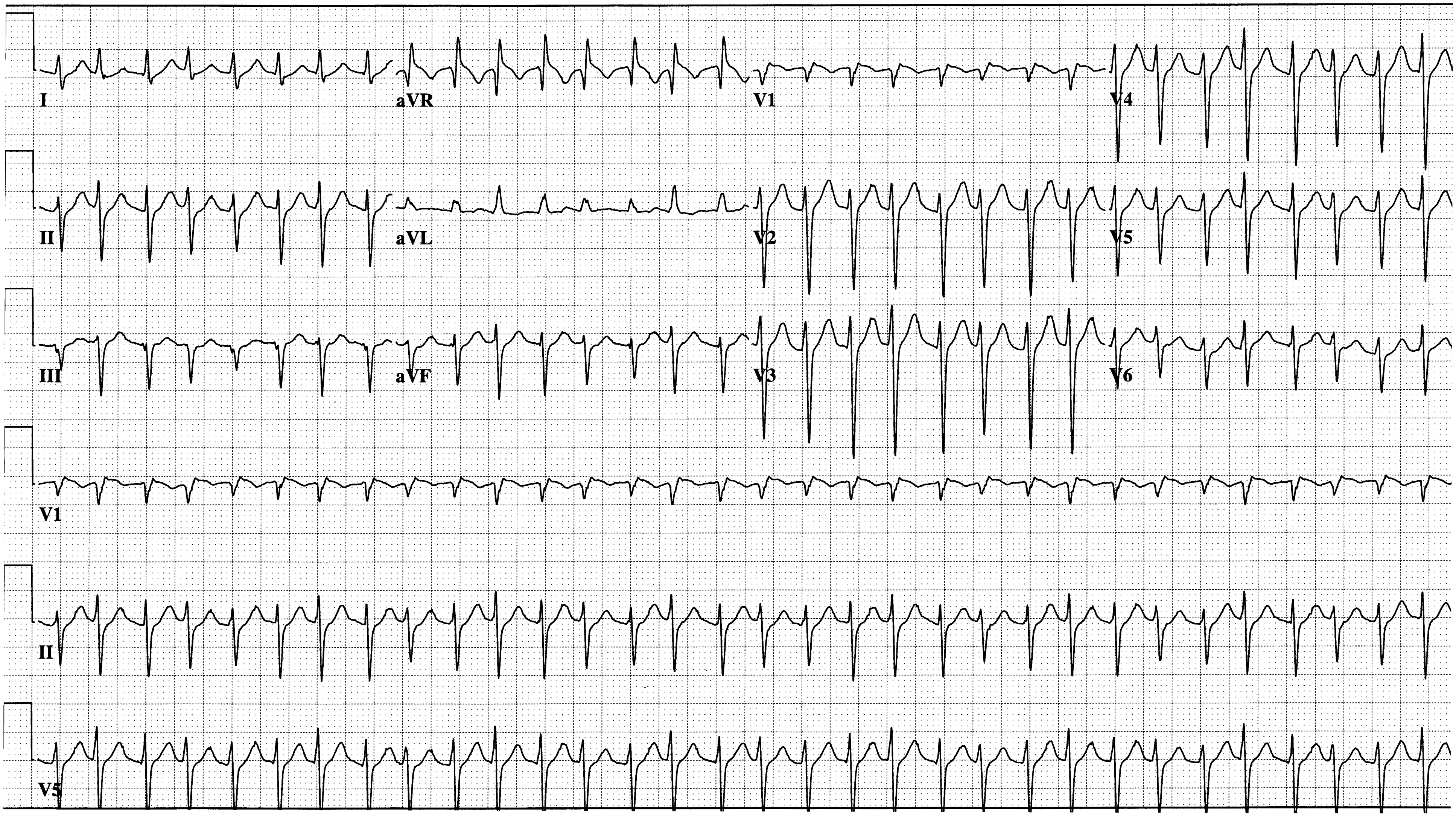
Atrial rate: ____________ QRS complex: ST segment: ____________

Ventricular rate: ____________ Axis: ____________ T wave: ____________

Rhythm: ____________ Duration: ____________ QT interval: ____________

P wave: ____________ Voltage: ____________ U wave: ____________

PR interval: ____________ Morphology: ____________ Diagnosis: ____________



ECG Review 17

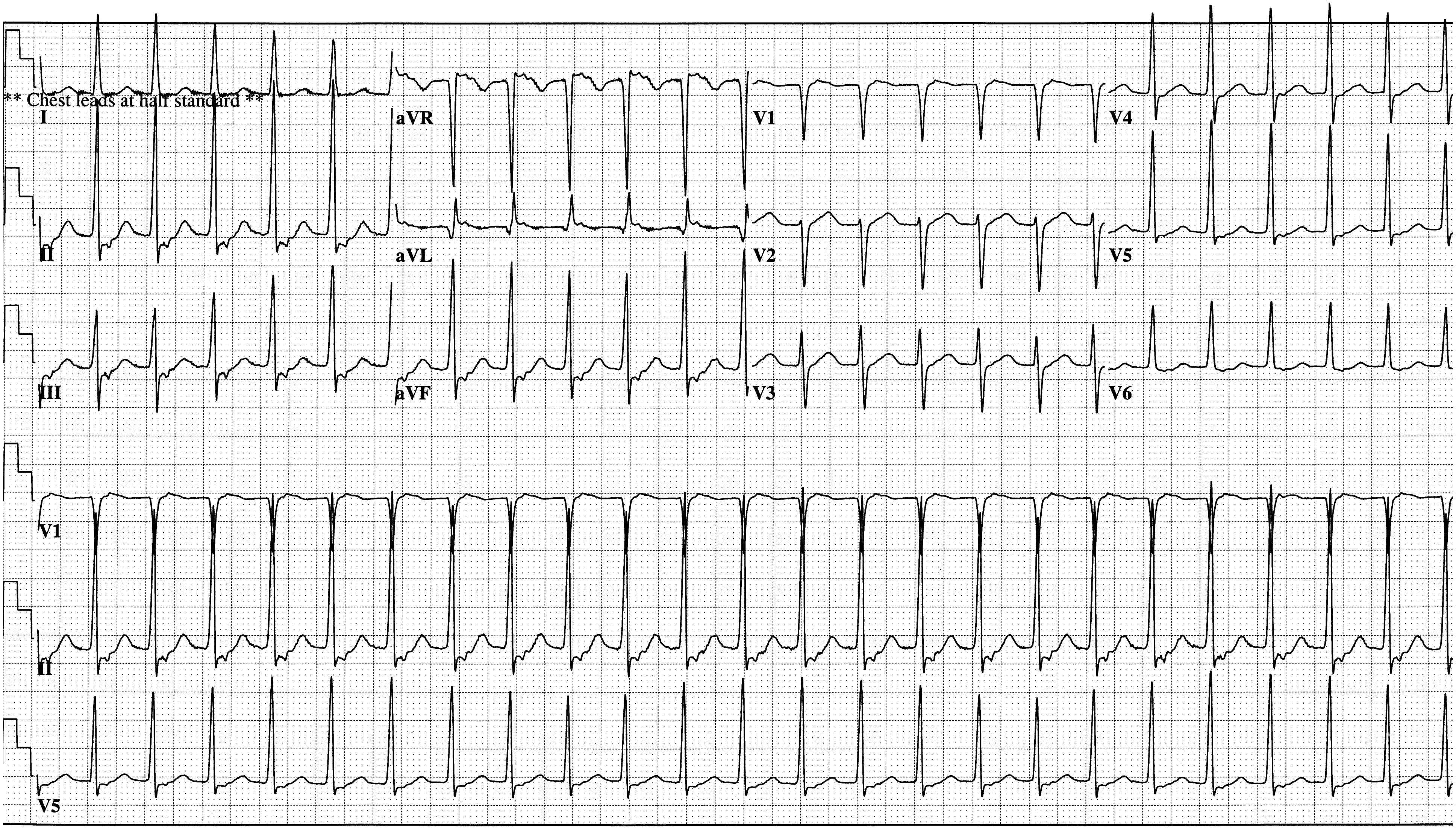
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG Review 18

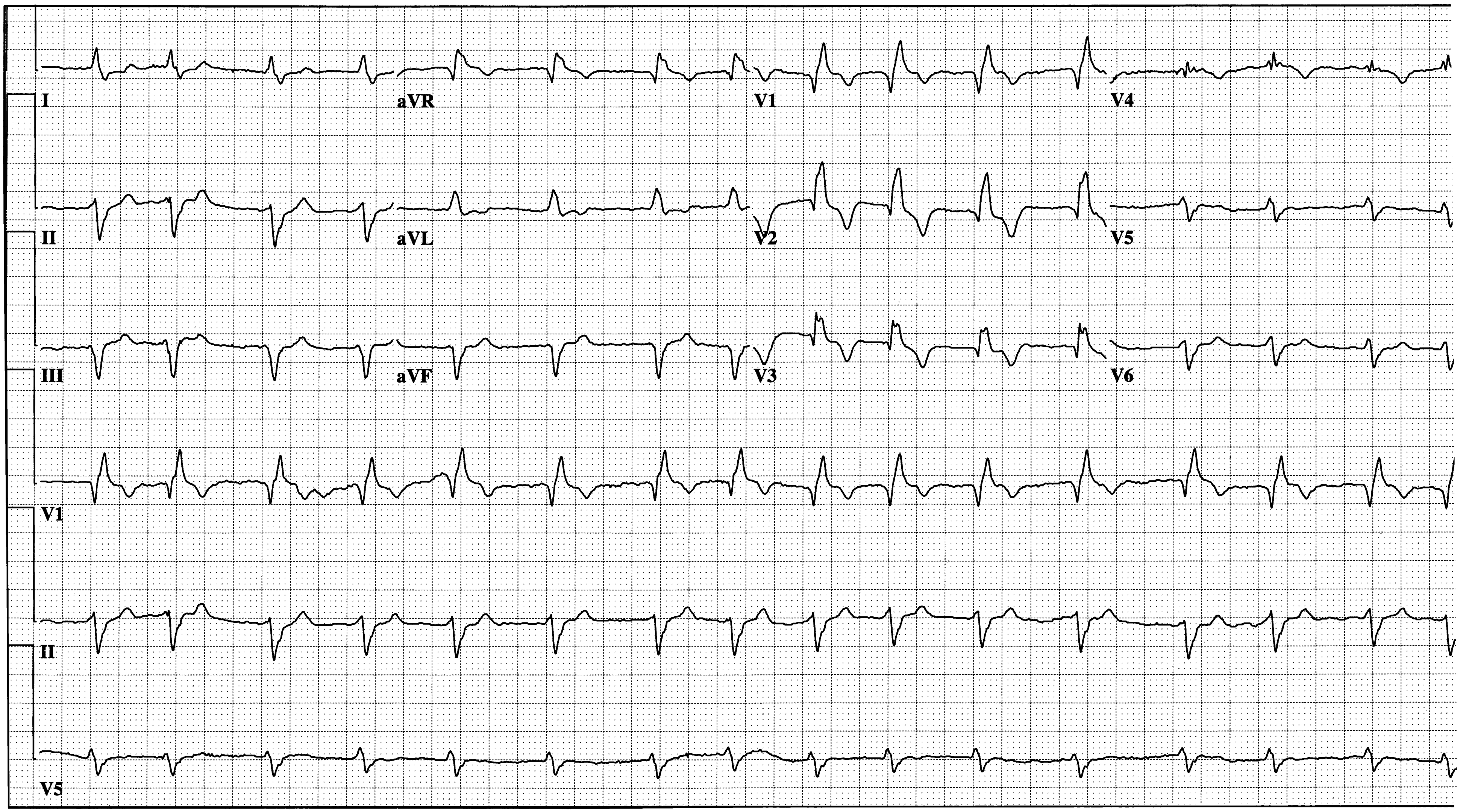
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG Review 19

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

ST segment: ____________________

T wave: ____________________

QT interval: ____________________

U wave: ____________________

Diagnosis: ____________________

ECG Review 20

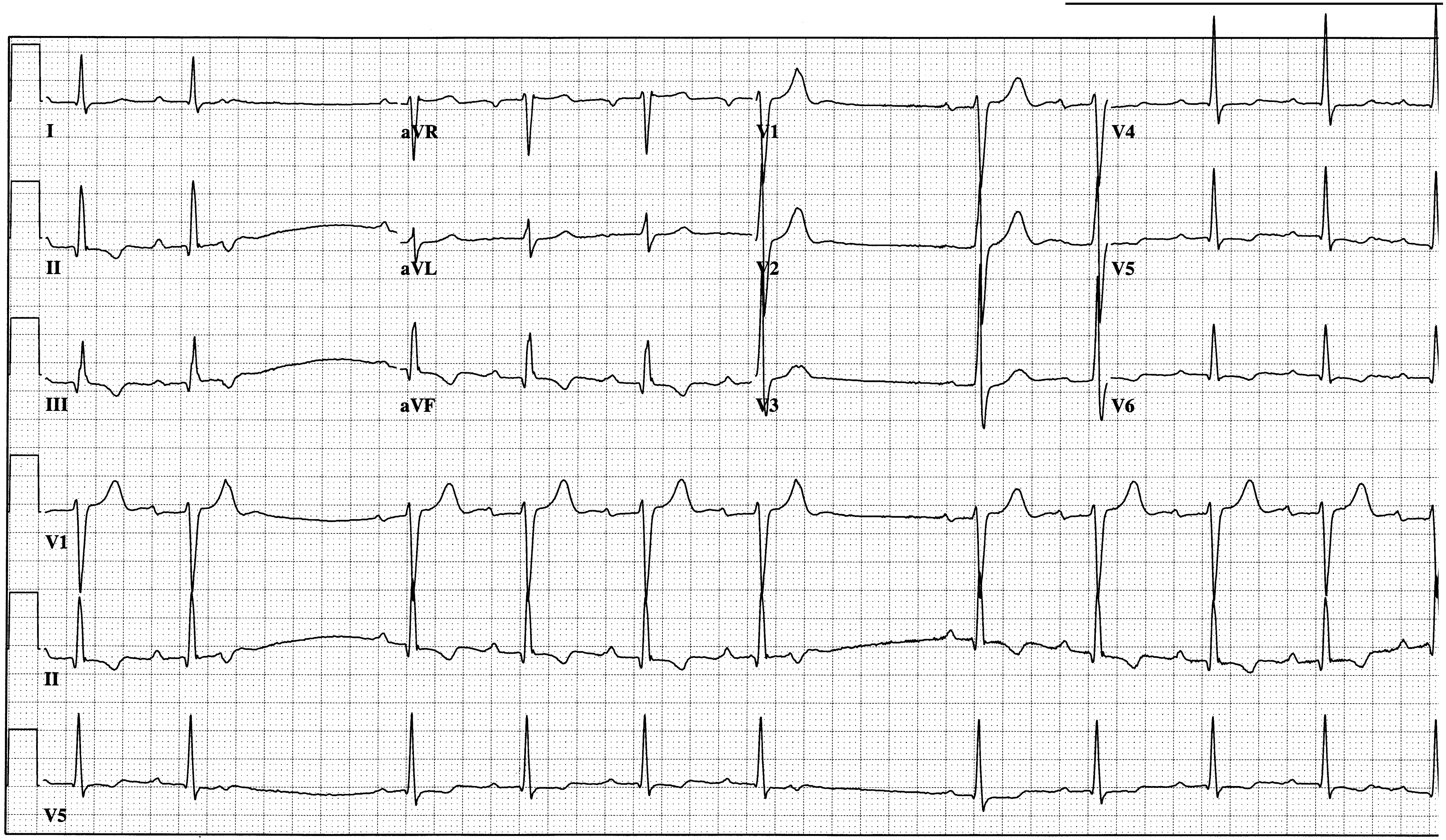
Atrial rate: ______________________ QRS complex: ST segment: ______________________

Ventricular rate: ______________________ Axis: ______________________ T wave: ______________________

Rhythm: ______________________ Duration: ______________________ QT interval: ______________________

P wave: ______________________ Voltage: ______________________ U wave: ______________________

PR interval: ______________________ Morphology: ______________________ Diagnosis: ______________________



ECG Review 21

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

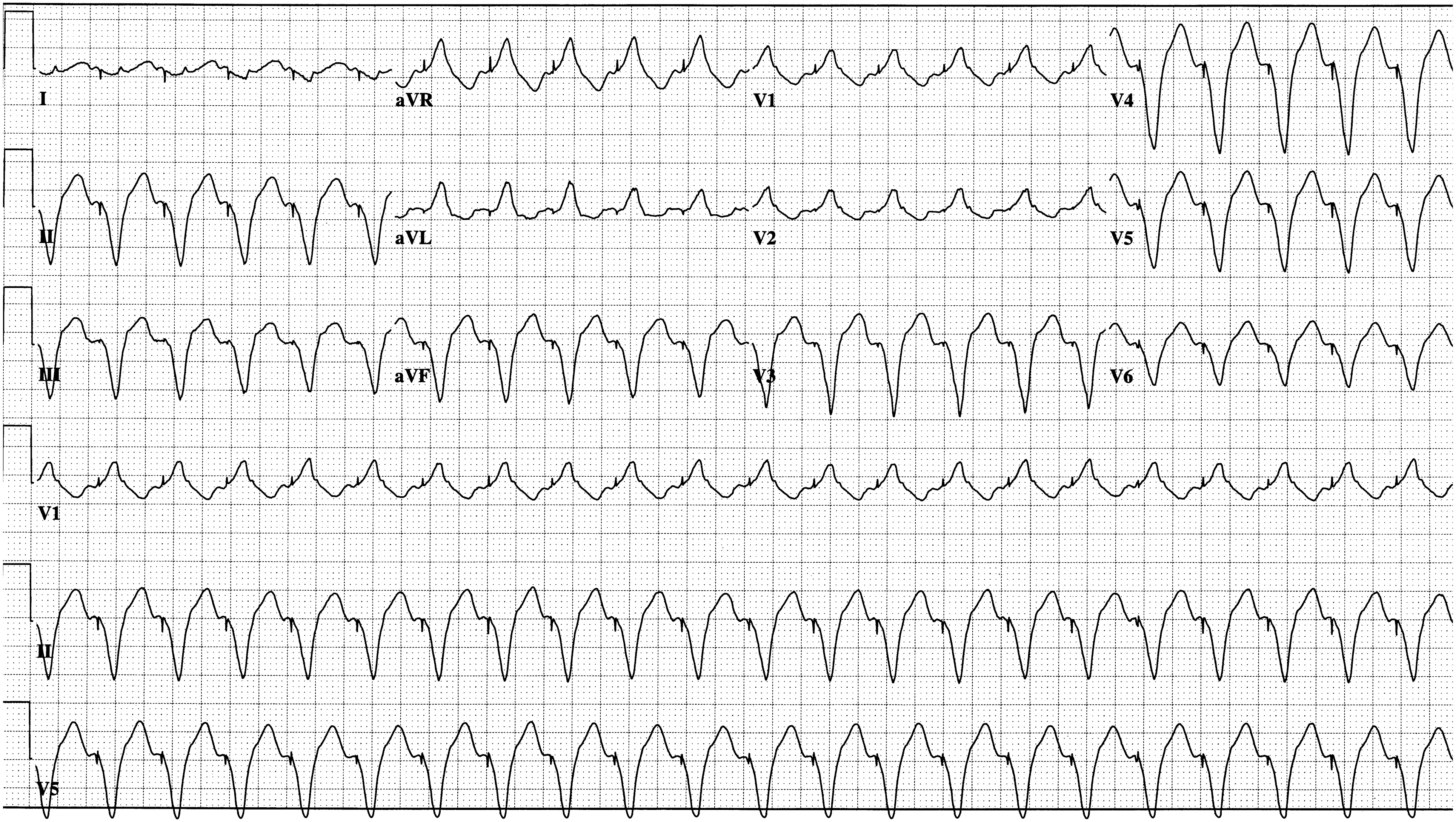
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______

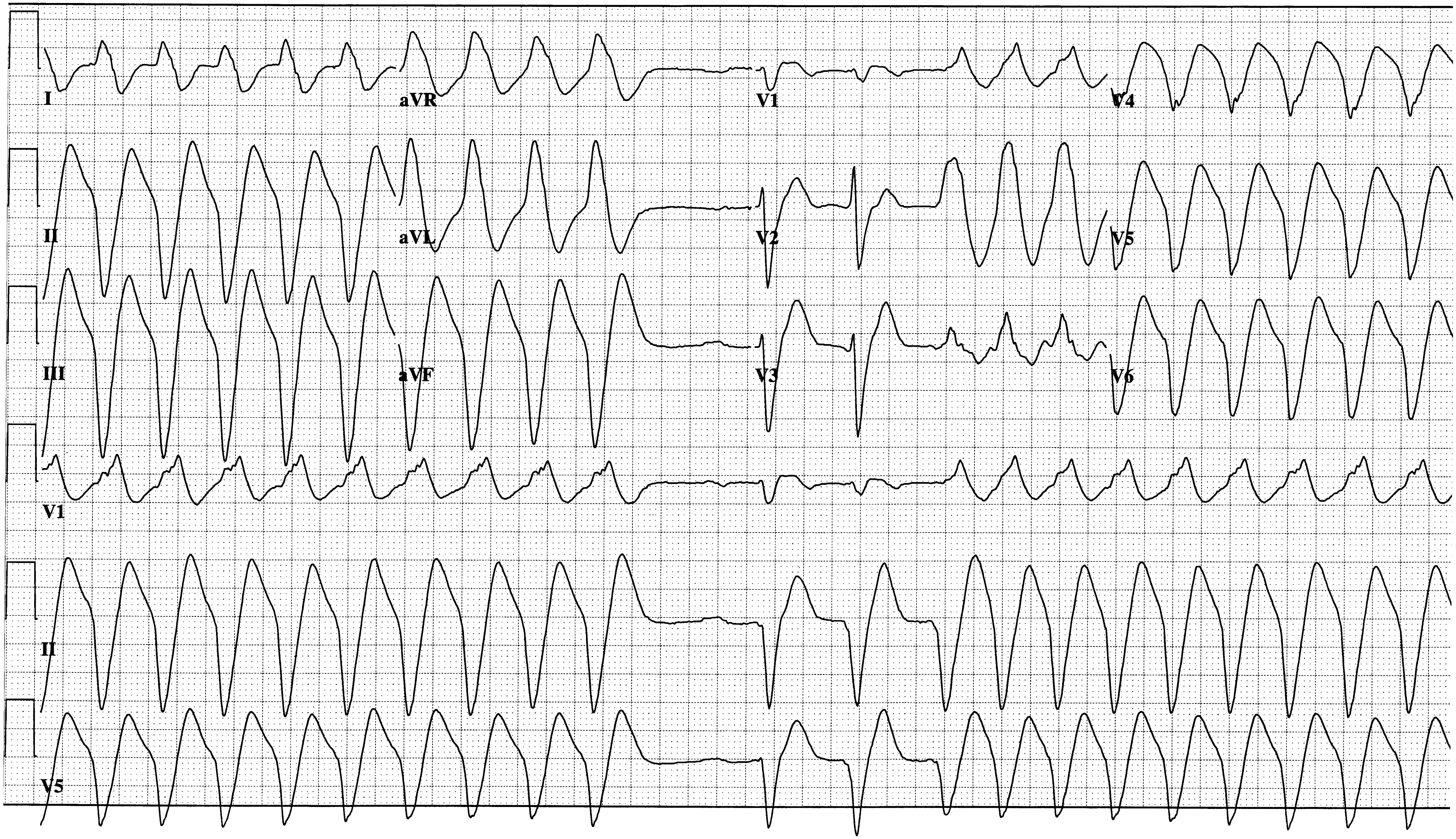


ECG Review 22

Atrial rate: ____________________
Ventricular rate: ____________________
Rhythm: ____________________
P wave: ____________________
PR interval: ____________________

QRS complex:
Axis: ____________________
Duration: ____________________
Voltage: ____________________
Morphology: ____________________

ST segment: ____________________
T wave: ____________________
QT interval: ____________________
U wave: ____________________
Diagnosis: ____________________

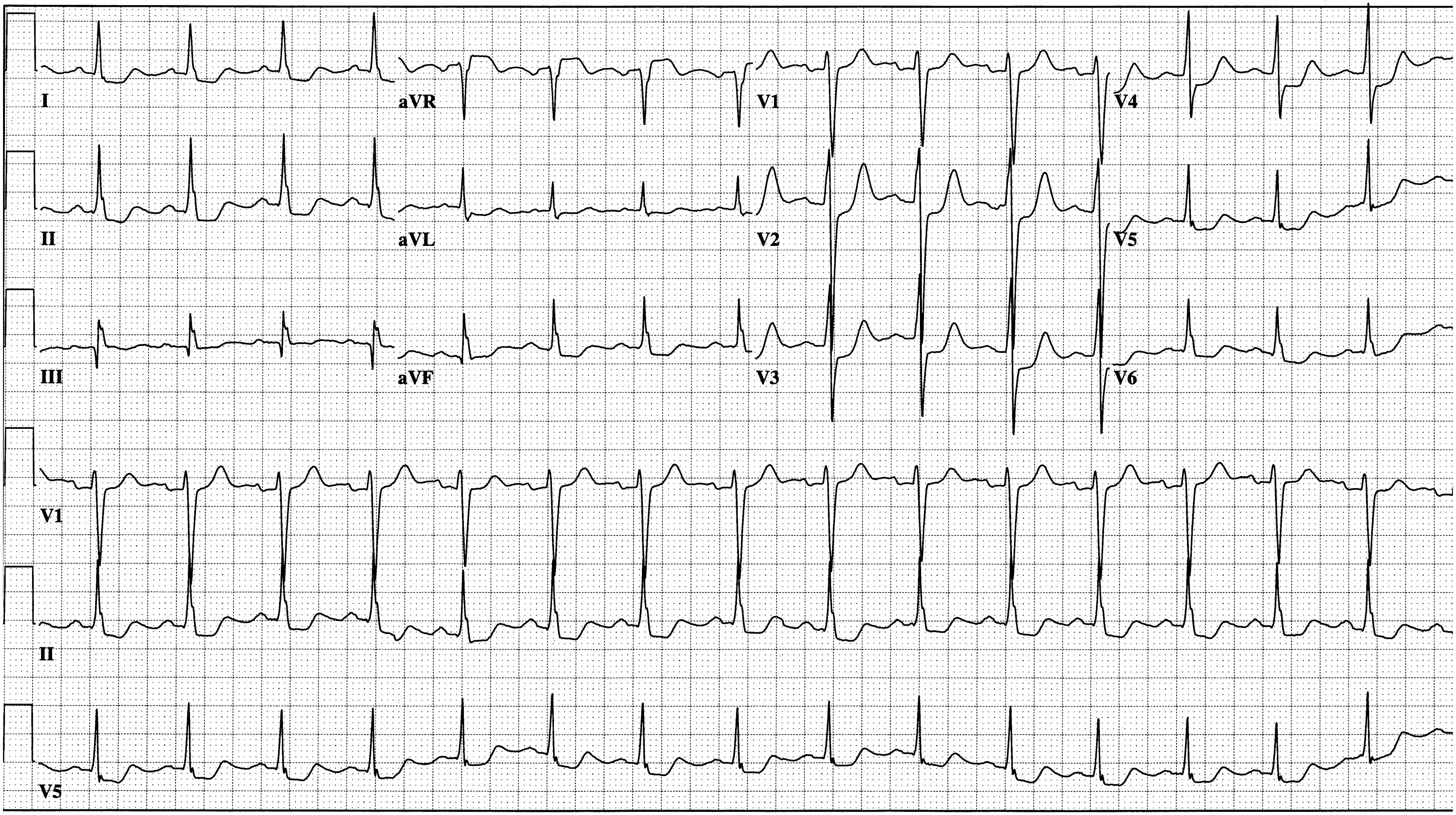


ECG Review 23

Atrial rate: ____________
Ventricular rate: ____________
Rhythm: ____________
P wave: ____________
PR interval: ____________

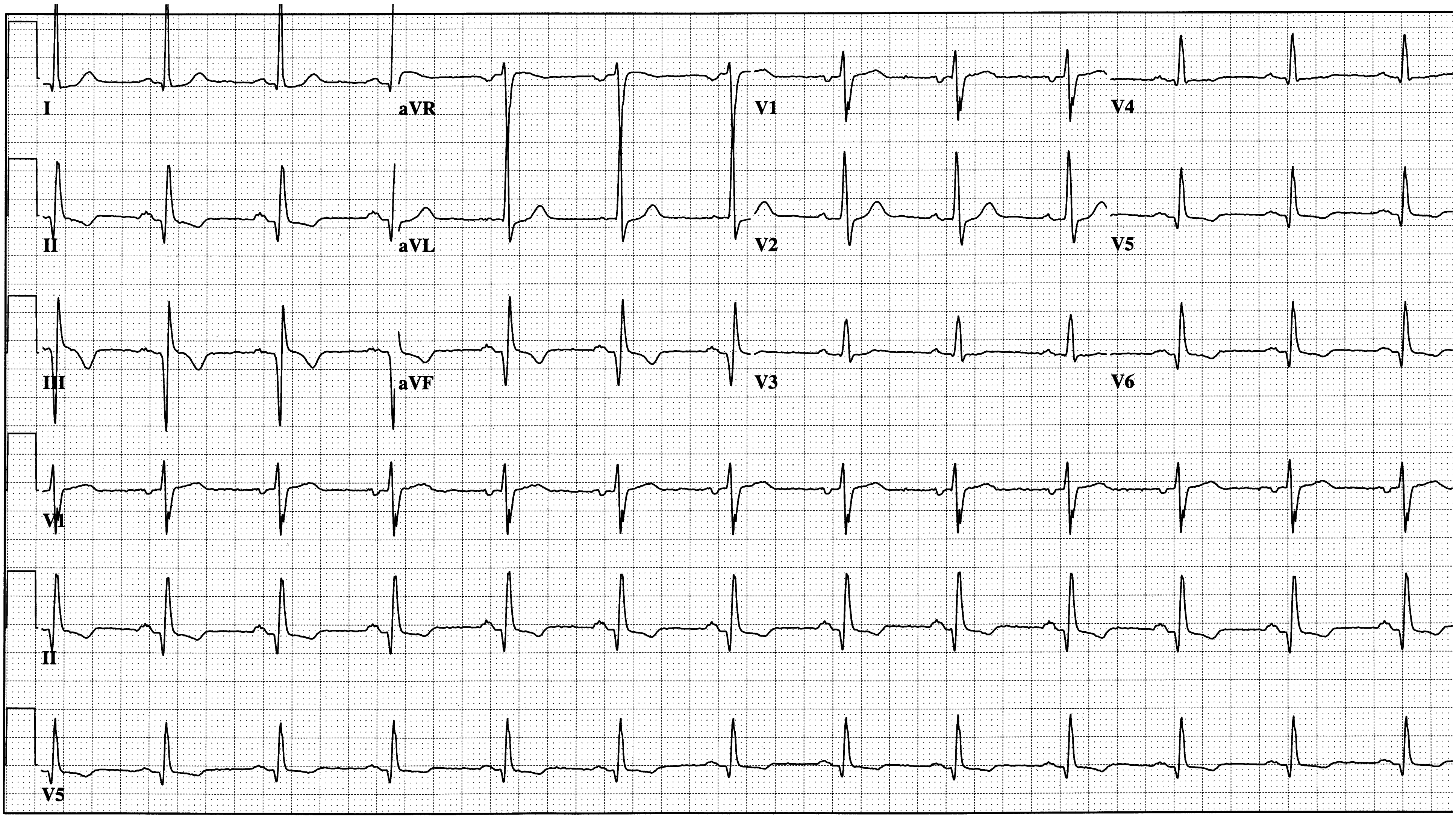
QRS complex:
Axis: ____________
Duration: ____________
Voltage: ____________
Morphology: ____________

ST segment: ____________
T wave: ____________
QT interval: ____________
U wave: ____________
Diagnosis: ____________



ECG Review 24

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG Review 25

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

ST segment: ____________________

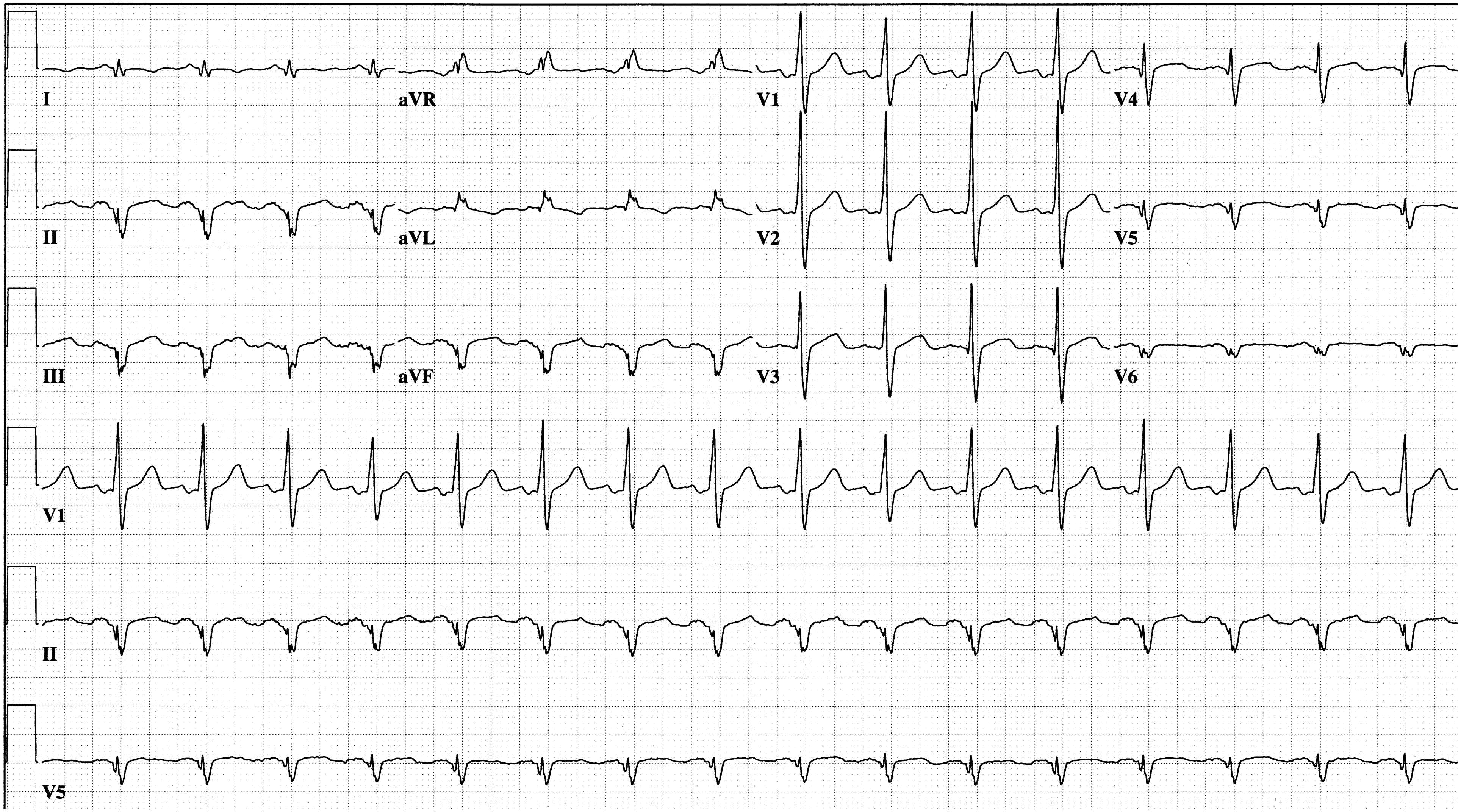
T wave: ____________________

QT interval: ____________________

U wave: ____________________

Diagnosis: ____________________

____



ECG Review 26

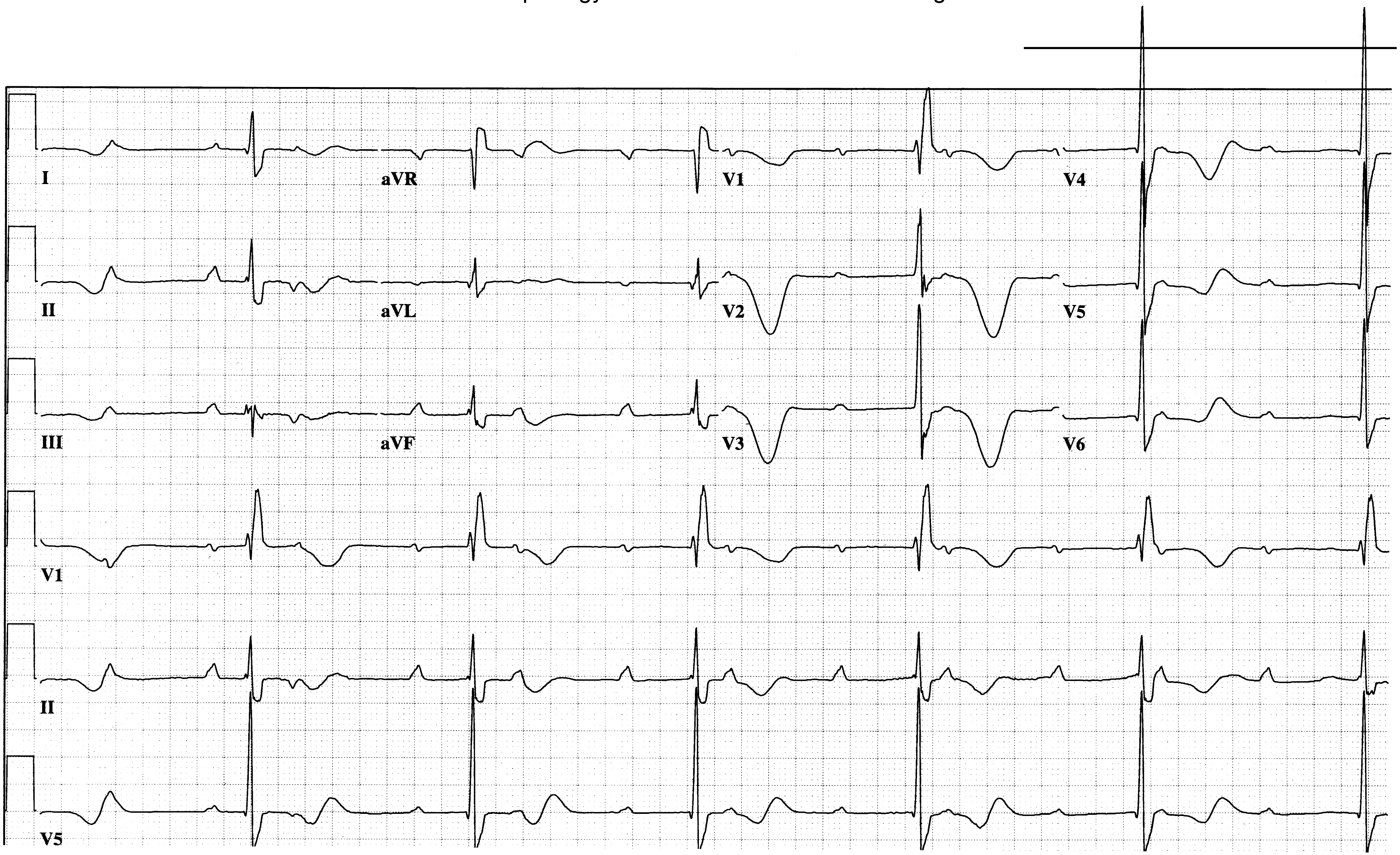
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG Review 27

Atrial rate: ____________

Ventricular rate: ____________

Rhythm: ____________

P wave: ____________

PR interval: ____________

QRS complex:

Axis: ____________

Duration: ____________

Voltage: ____________

Morphology: ____________

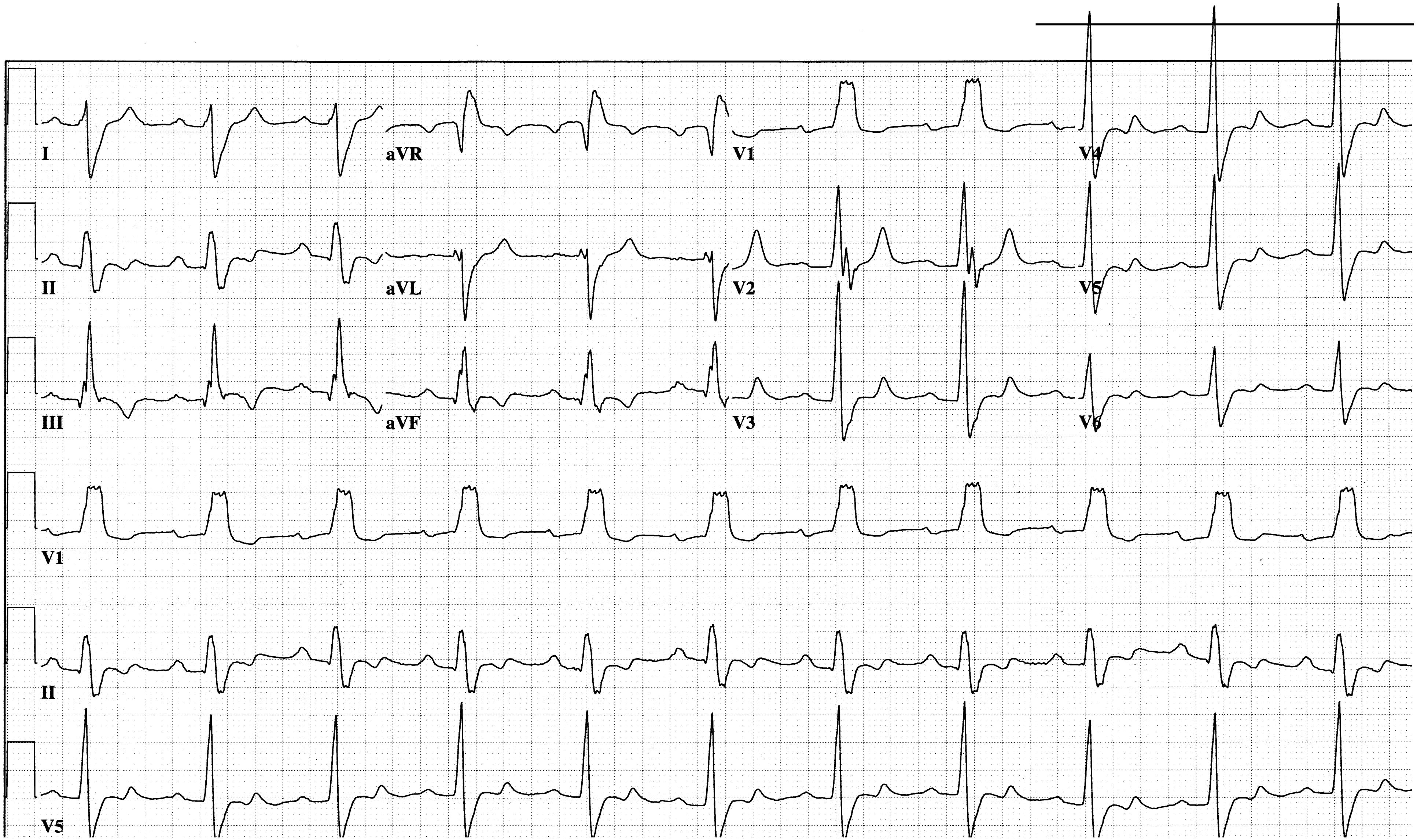
ST segment: ____________

T wave: ____________

QT interval: ____________

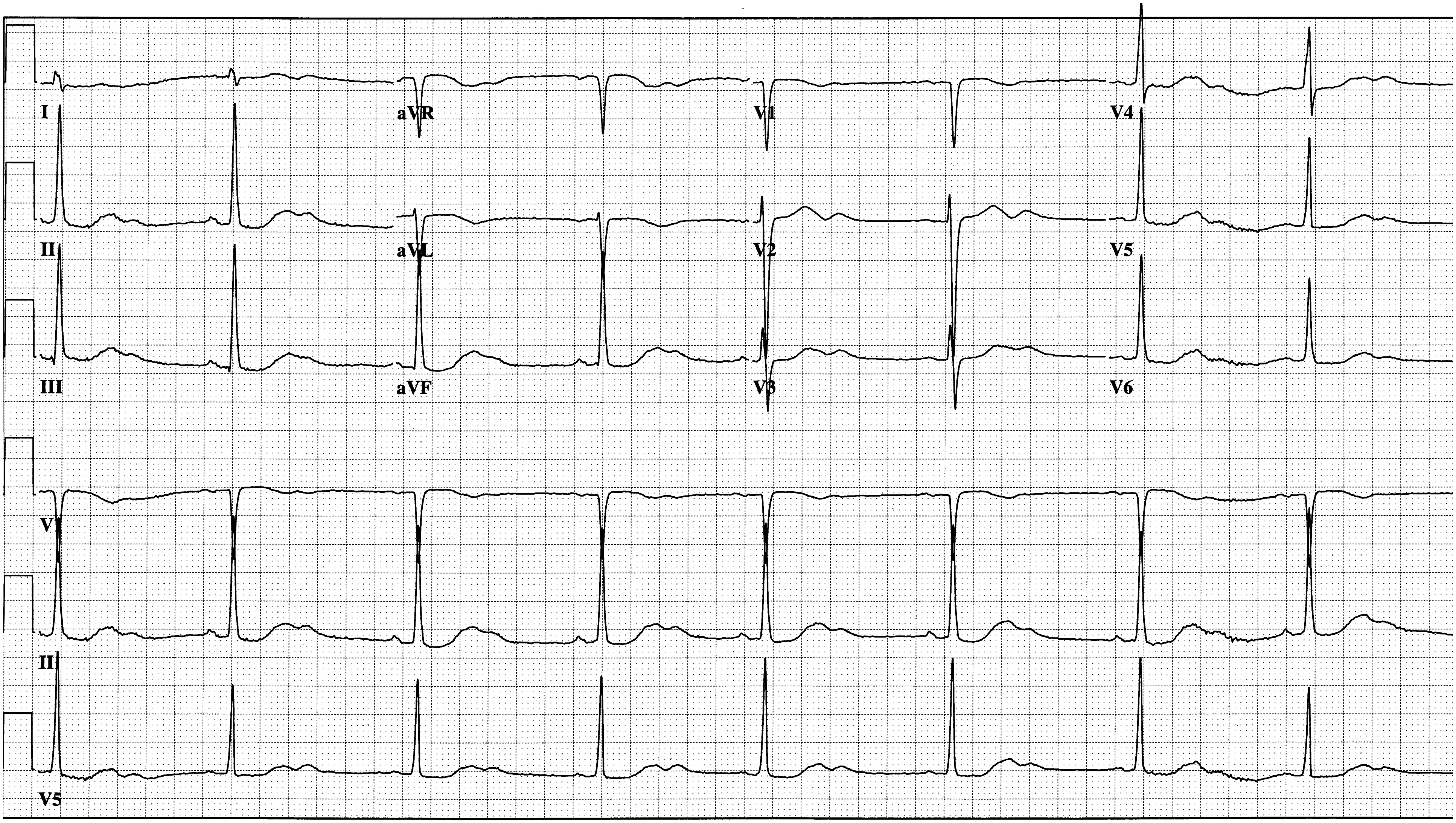
U wave: ____________

Diagnosis: ____________



ECG Review 28

Sinus bardycardia, voltage criteria for LVH, and prominent U waves. The U waves could be secondary to LVH or other conditions such as hypokalemia or ischemia



ECG Review 29

Atrial rate: ________

Ventricular rate: ________

Rhythm: ________

P wave: ________

PR interval: ________

QRS complex:

Axis: ________

Duration: ________

Voltage: ________

Morphology: ________

ST segment: ________

T wave: ________

QT interval: ________

U wave: ________

Diagnosis: ________

ECG Review 30

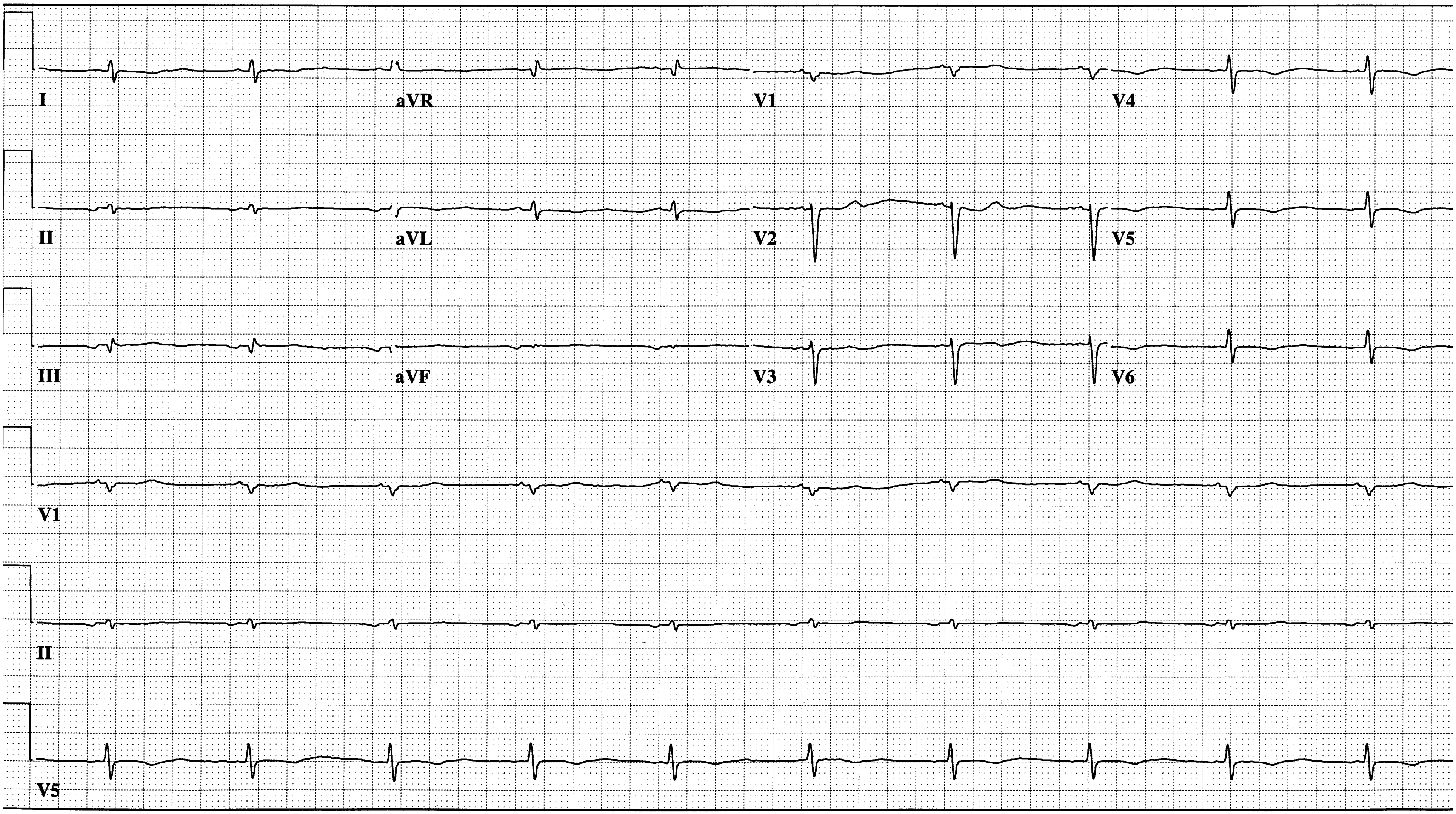
Atrial rate: ______________________ QRS complex: ST segment: ______________________

Ventricular rate: ______________________ Axis: ______________________ T wave: ______________________

Rhythm: ______________________ Duration: ______________________ QT interval: ______________________

P wave: ______________________ Voltage: ______________________ U wave: ______________________

PR interval: ______________________ Morphology: ______________________ Diagnosis: ______________________



ECG Review 31

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

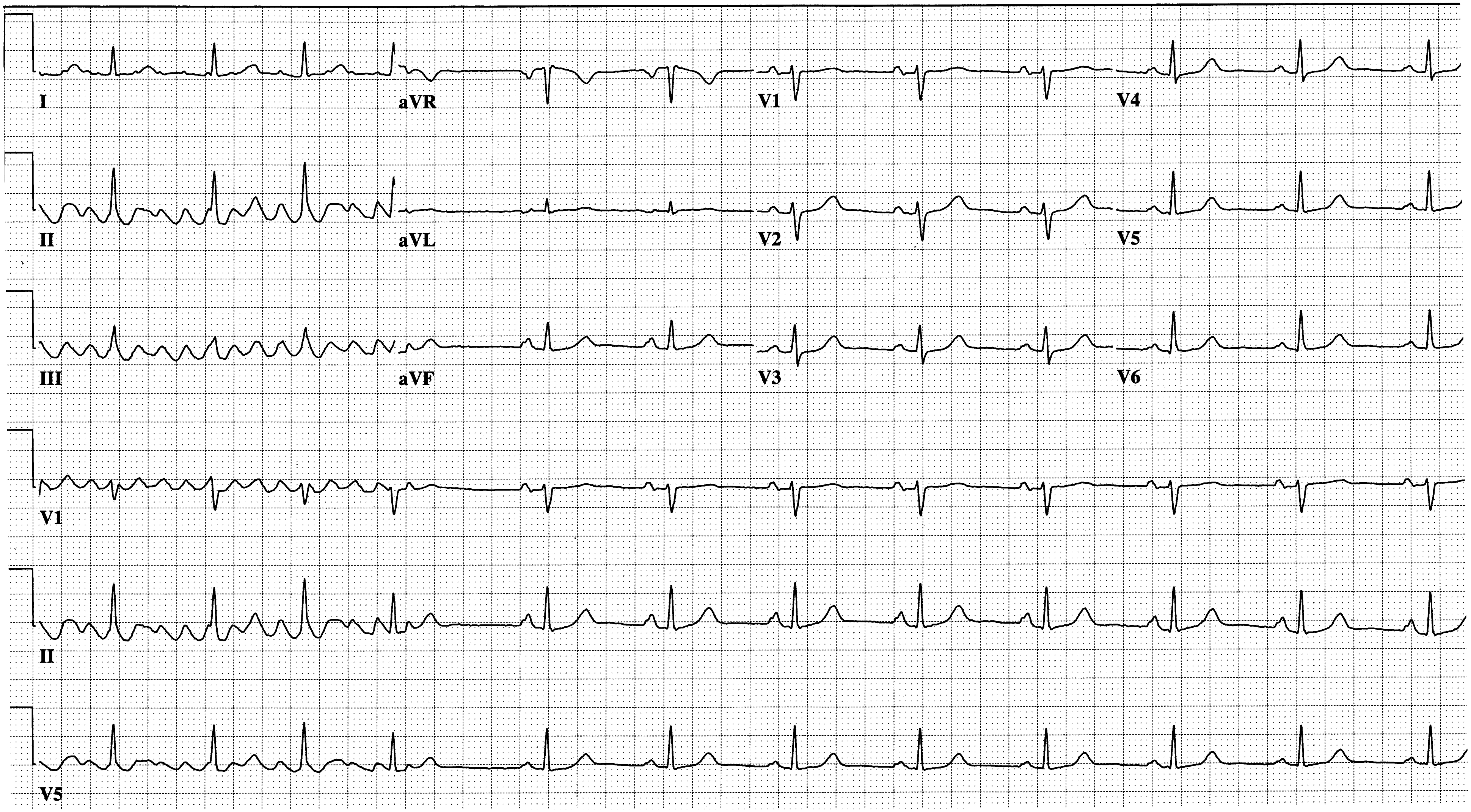
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG Review 32

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

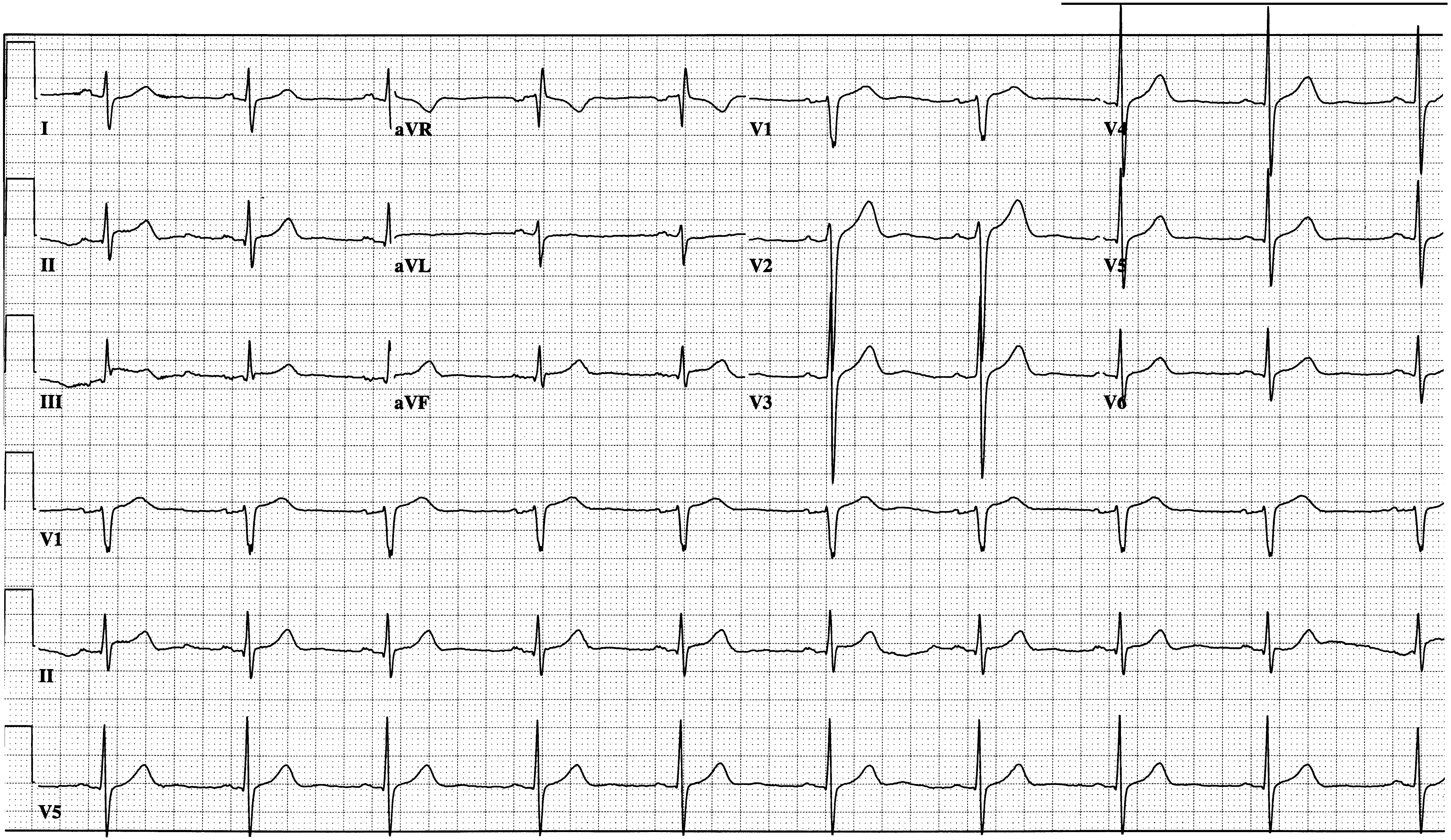
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG Review 33

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______

ECG Review 34

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

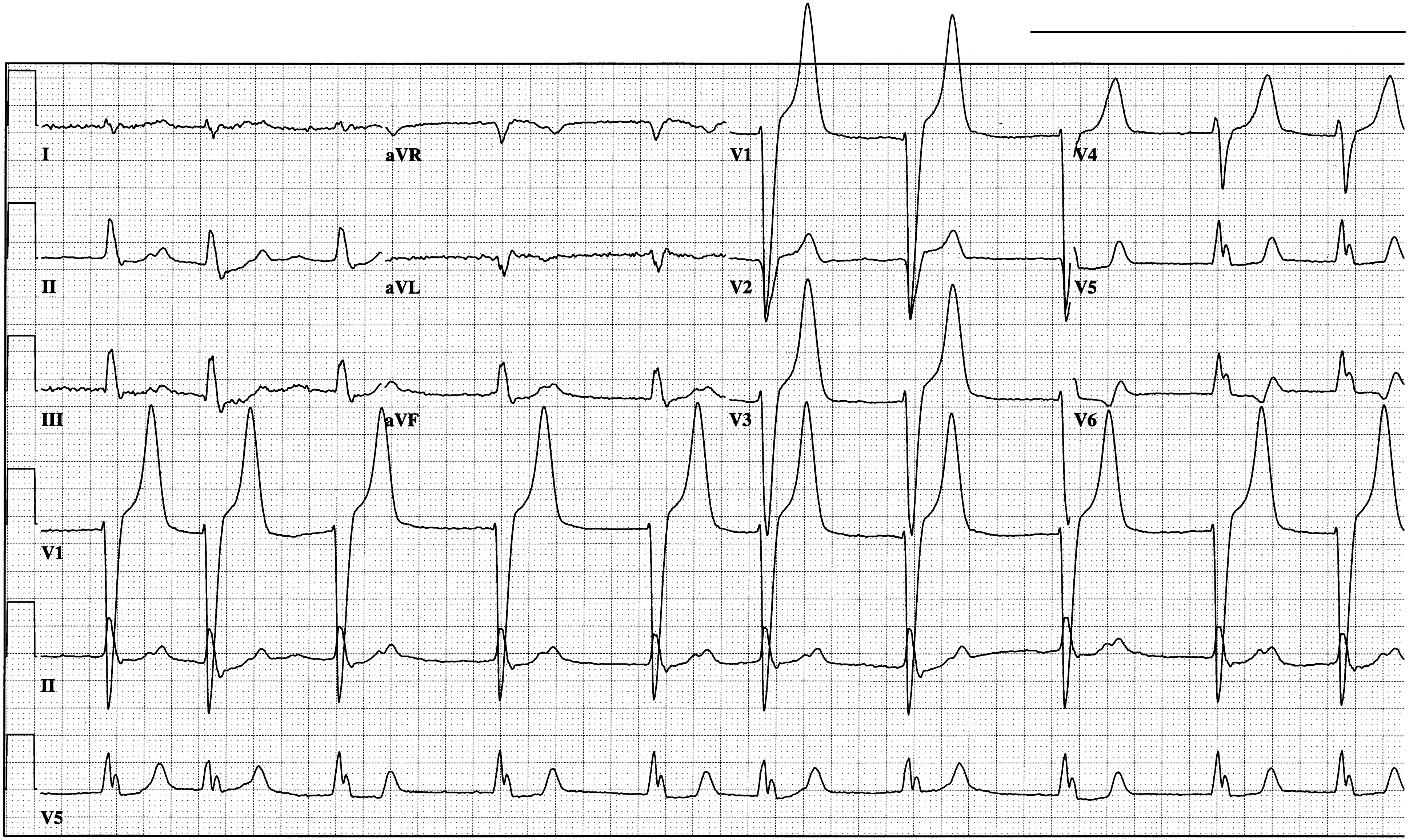
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG Review 35

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

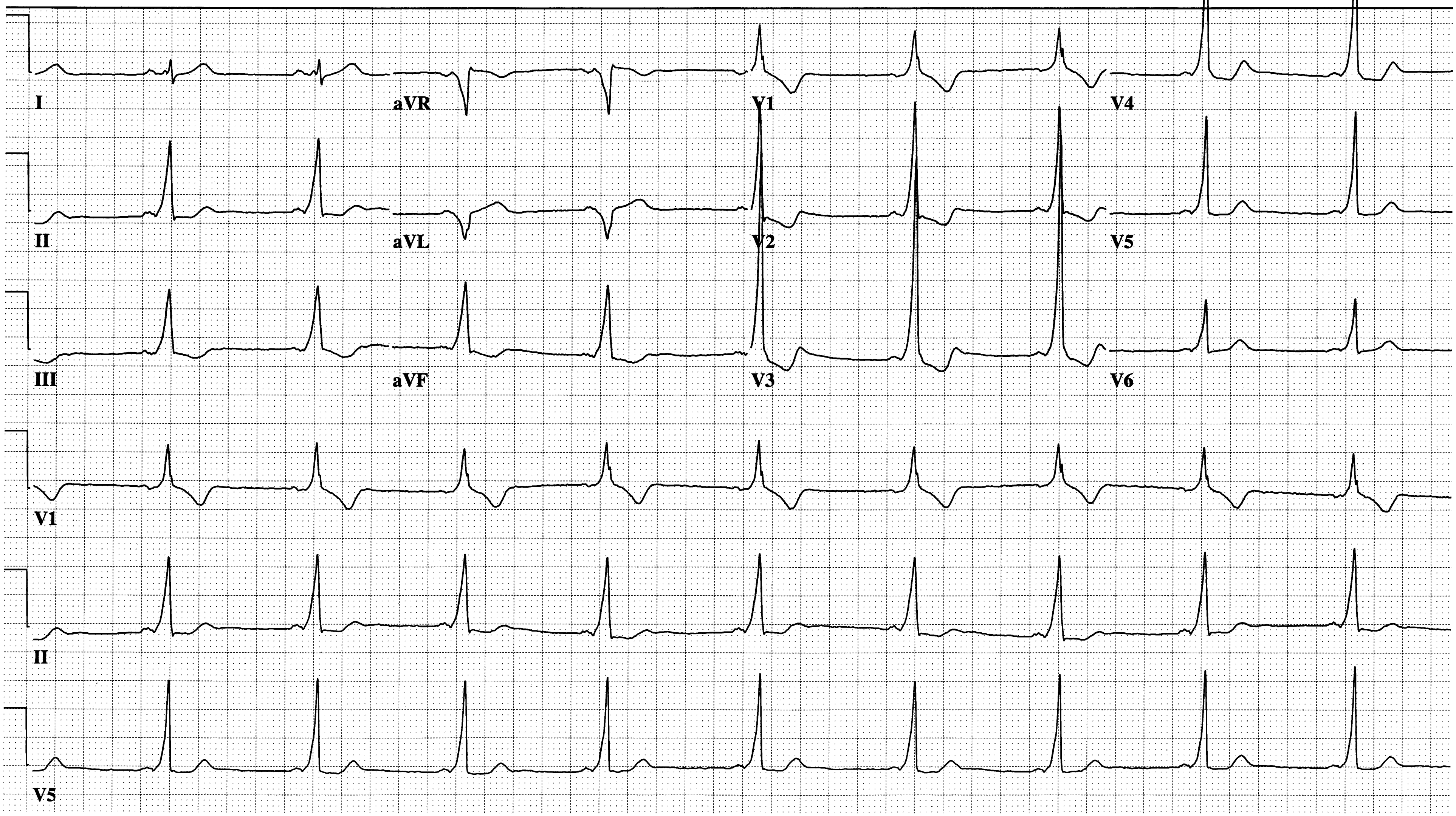
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______

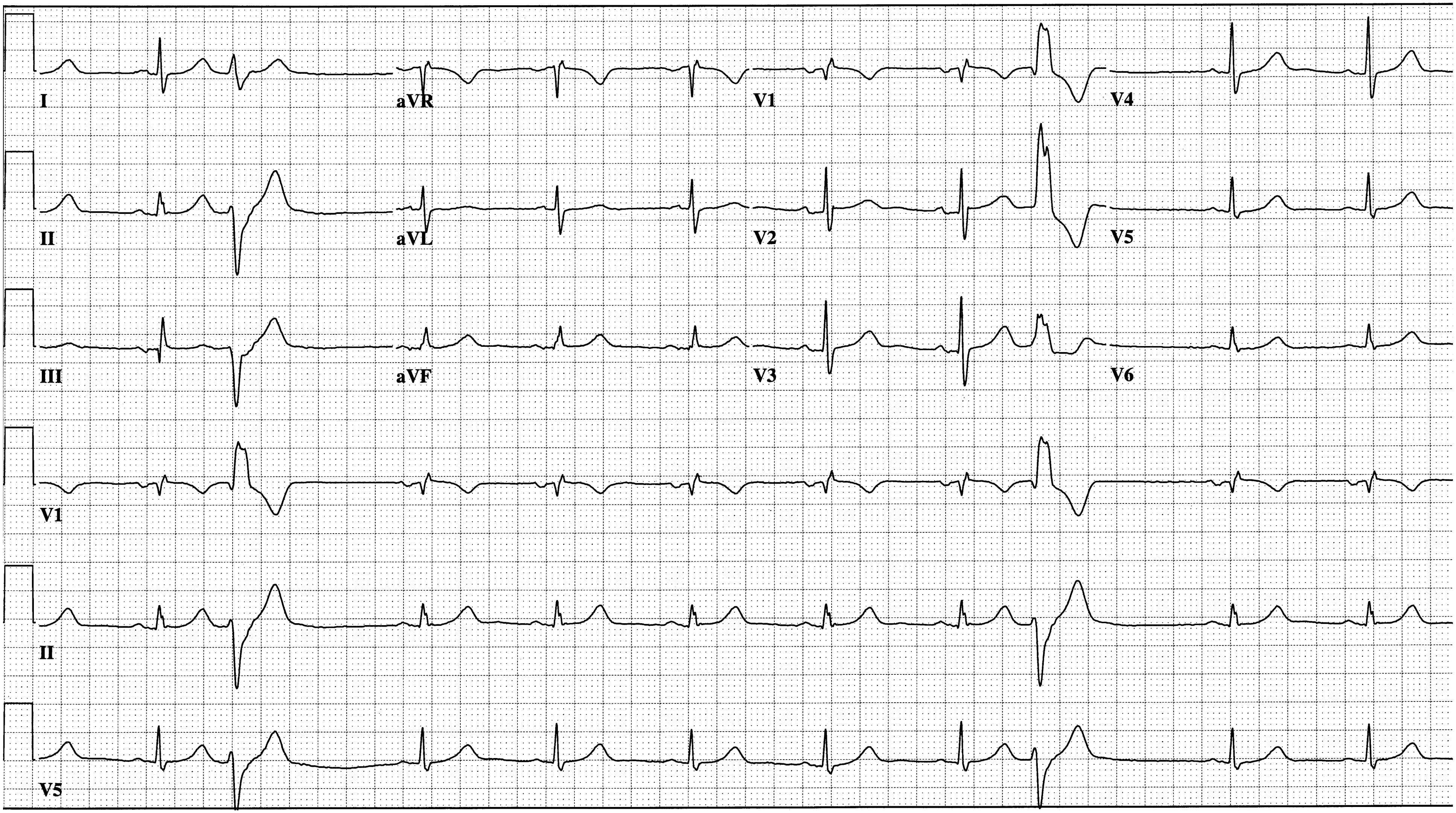


ECG Review 36

Atrial rate: __________
Ventricular rate: __________
Rhythm: __________
P wave: __________
PR interval: __________

QRS complex:
Axis: __________
Duration: __________
Voltage: __________
Morphology: __________

ST segment: __________
T wave: __________
QT interval: __________
U wave: __________
Diagnosis: __________



ECG Review 37

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

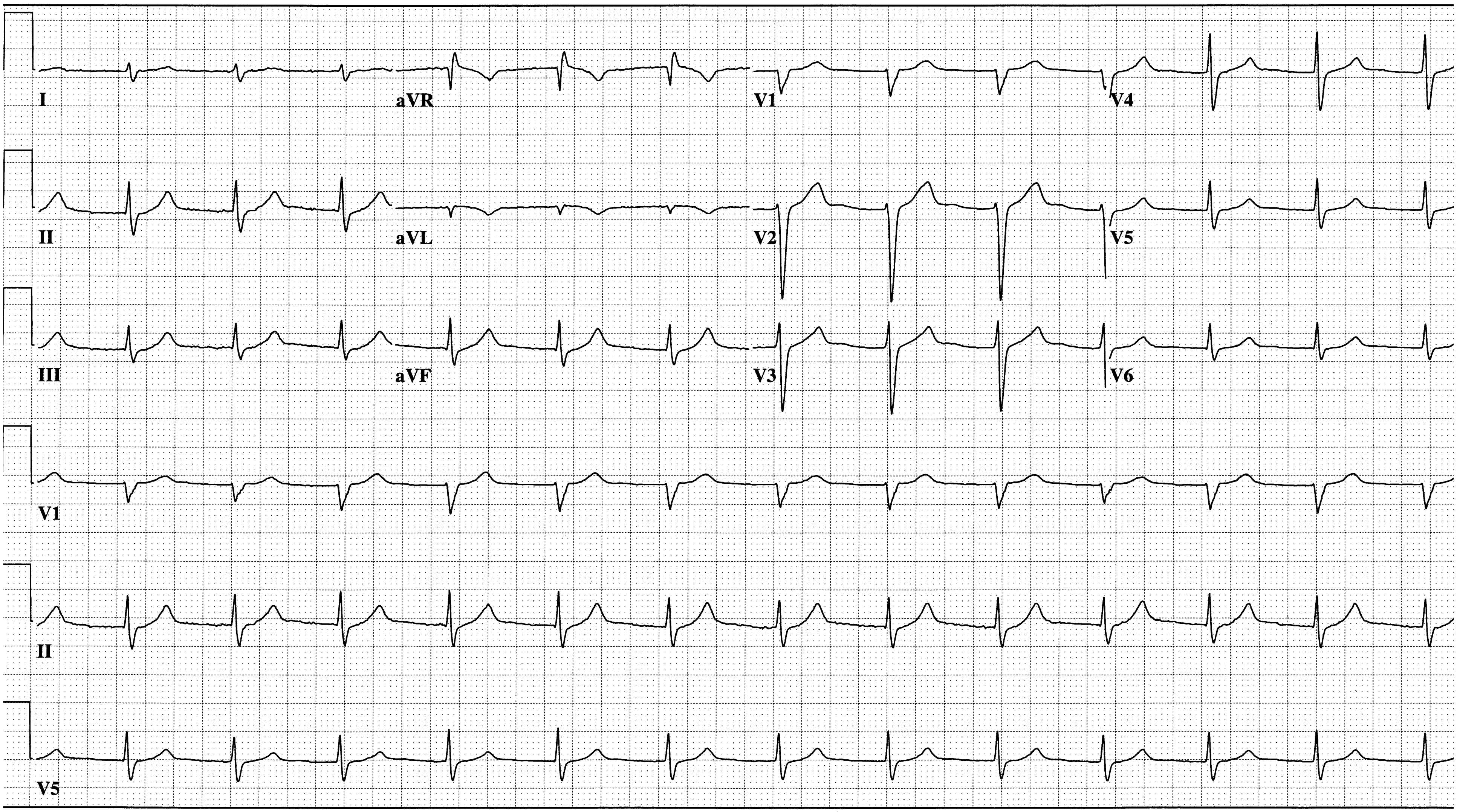
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG Review 38

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

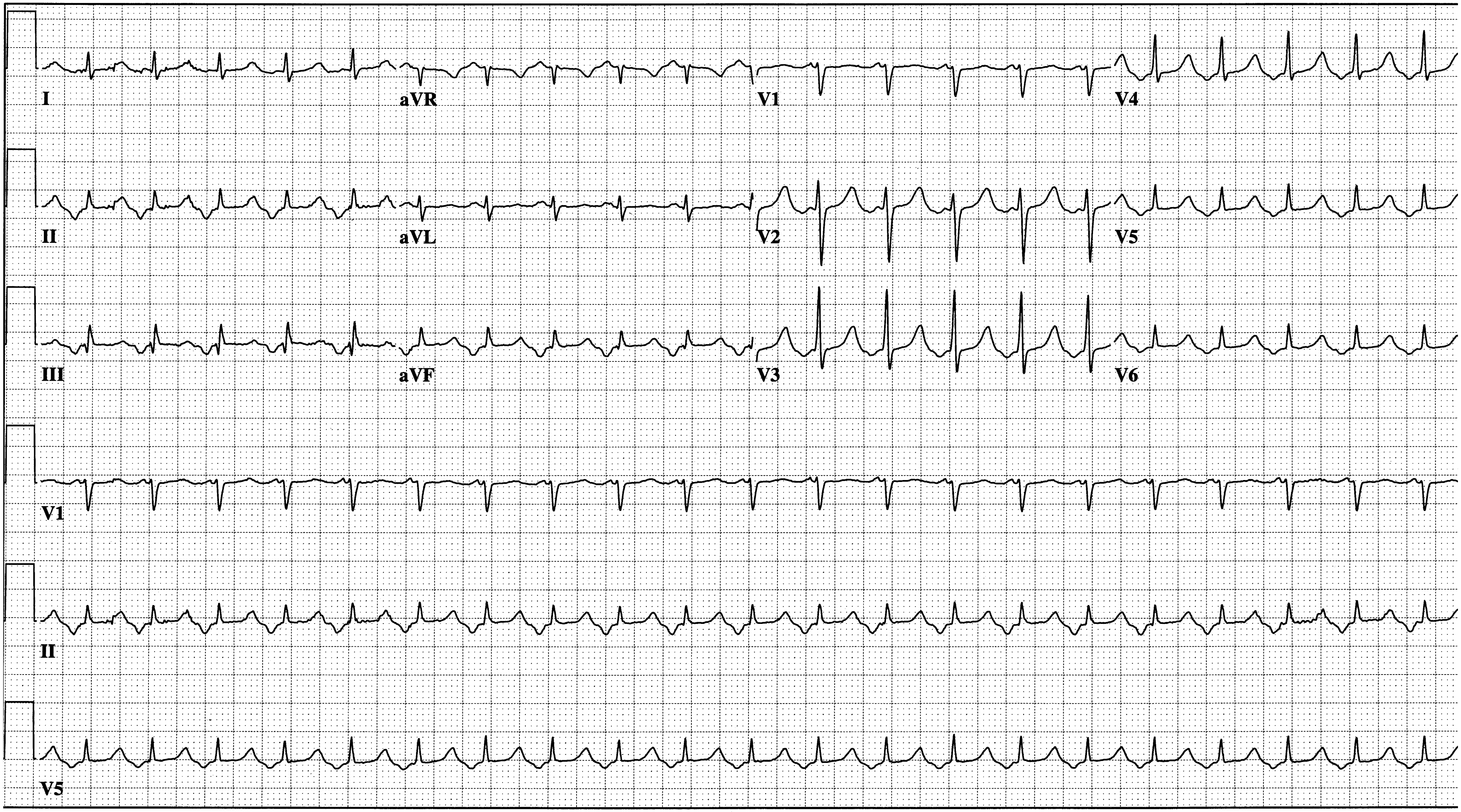
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG Review 39

Atrial rate: __________

Ventricular rate: __________

Rhythm: __________

P wave: __________

PR interval: __________

QRS complex:

Axis: __________

Duration: __________

Voltage: __________

Morphology: __________

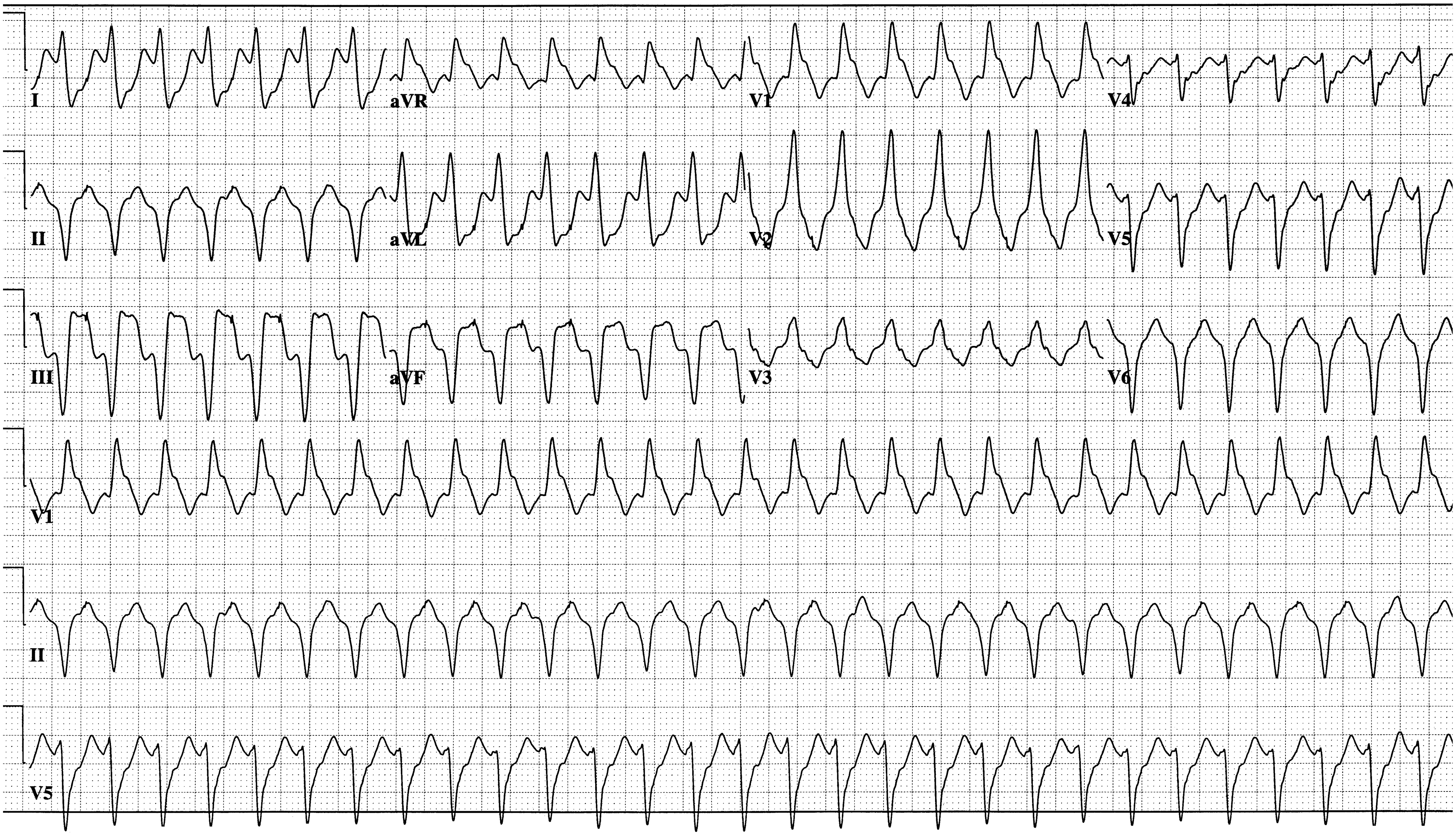
ST segment: __________

T wave: __________

QT interval: __________

U wave: __________

Diagnosis: __________



ECG Review 40

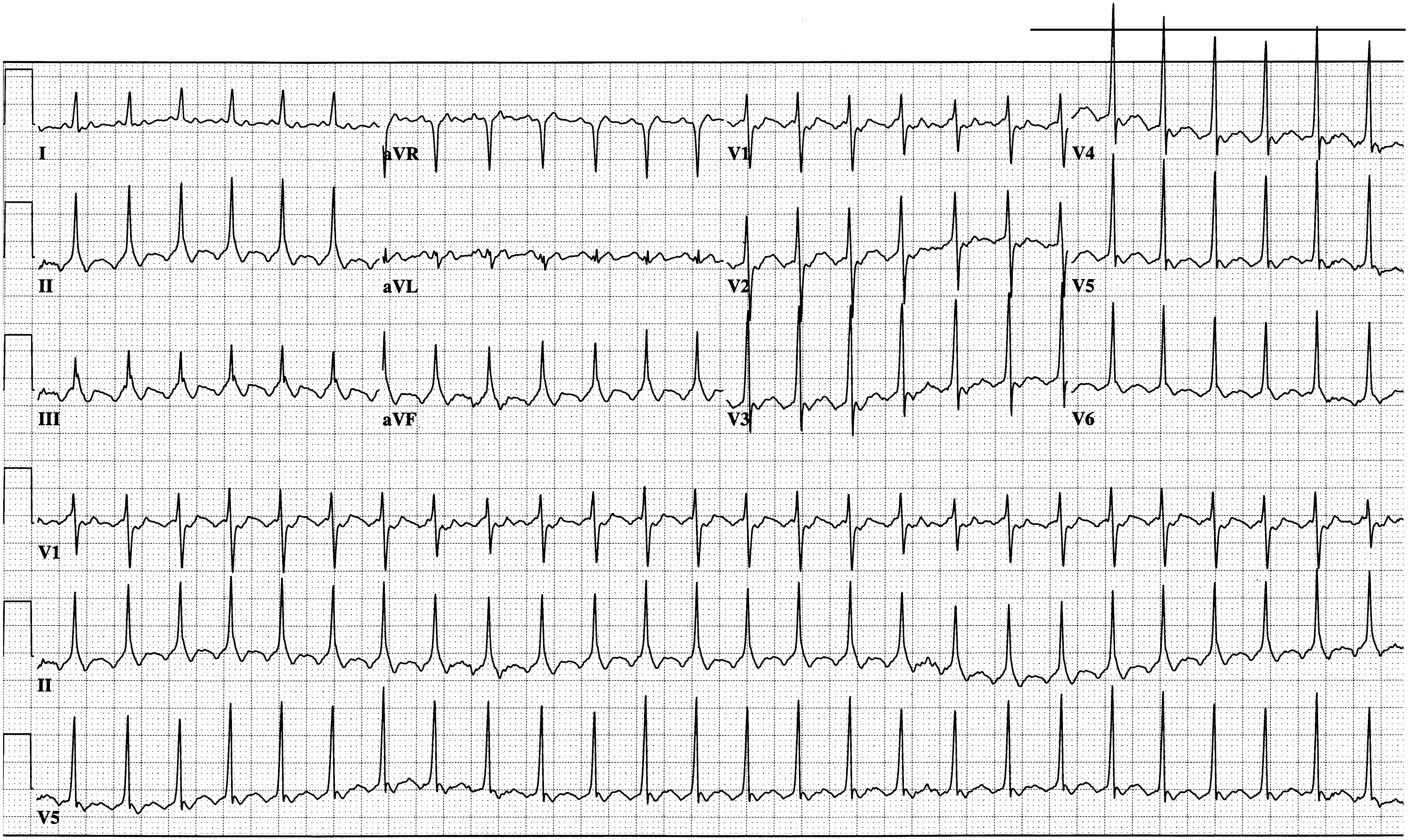
Atrial rate: ____________ QRS complex: ST segment: ____________

Ventricular rate: ____________ Axis: ____________ T wave: ____________

Rhythm: ____________ Duration: ____________ QT interval: ____________

P wave: ____________ Voltage: ____________ U wave: ____________

PR interval: ____________ Morphology: ____________ Diagnosis: ____________



ECG Review 41

Atrial rate: ____________

Ventricular rate: ____________

Rhythm: ____________

P wave: ____________

PR interval: ____________

QRS complex:

Axis: ____________

Duration: ____________

Voltage: ____________

Morphology: ____________

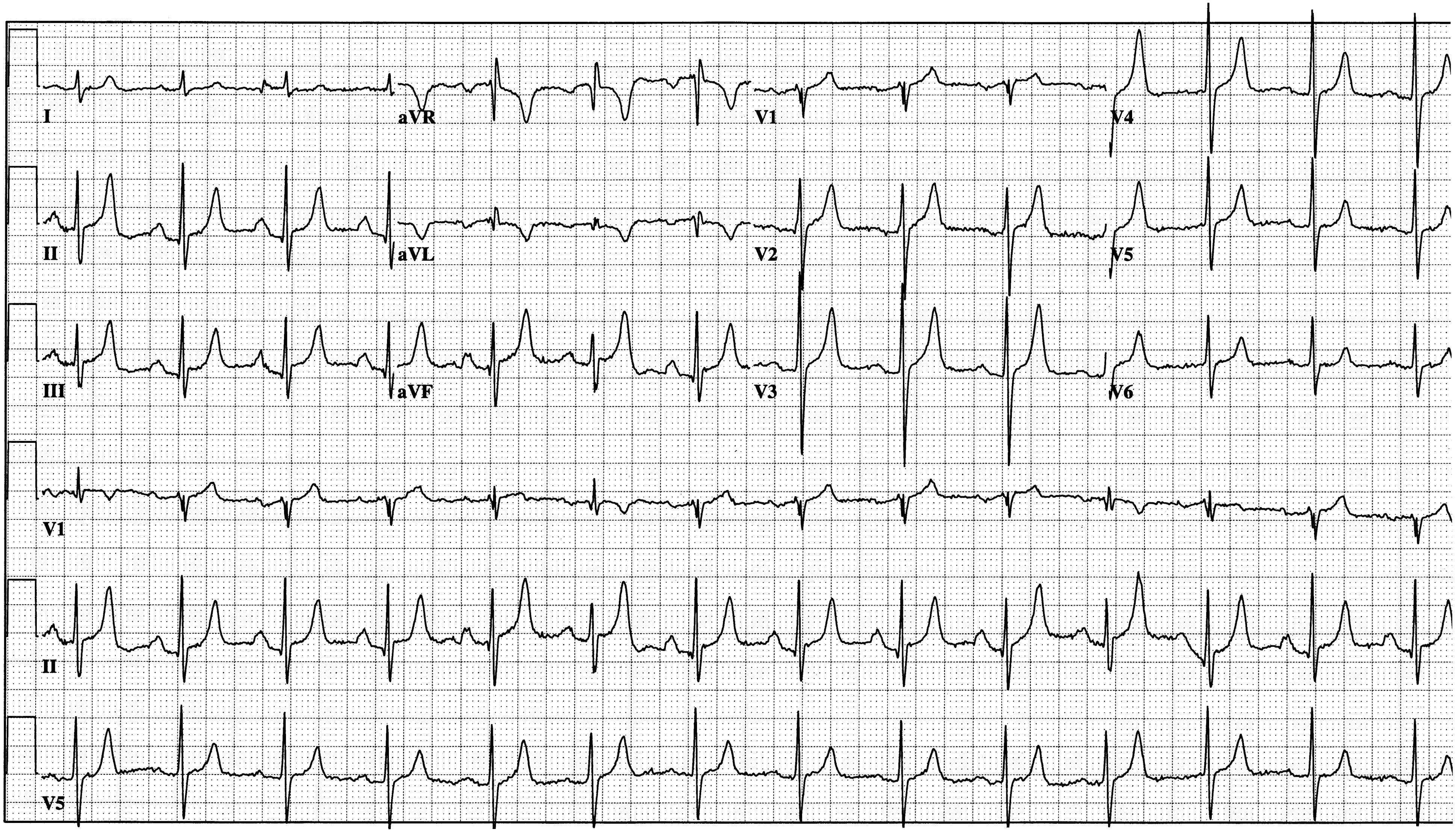
ST segment: ____________

T wave: ____________

QT interval: ____________

U wave: ____________

Diagnosis: ____________



ECG Review 42

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

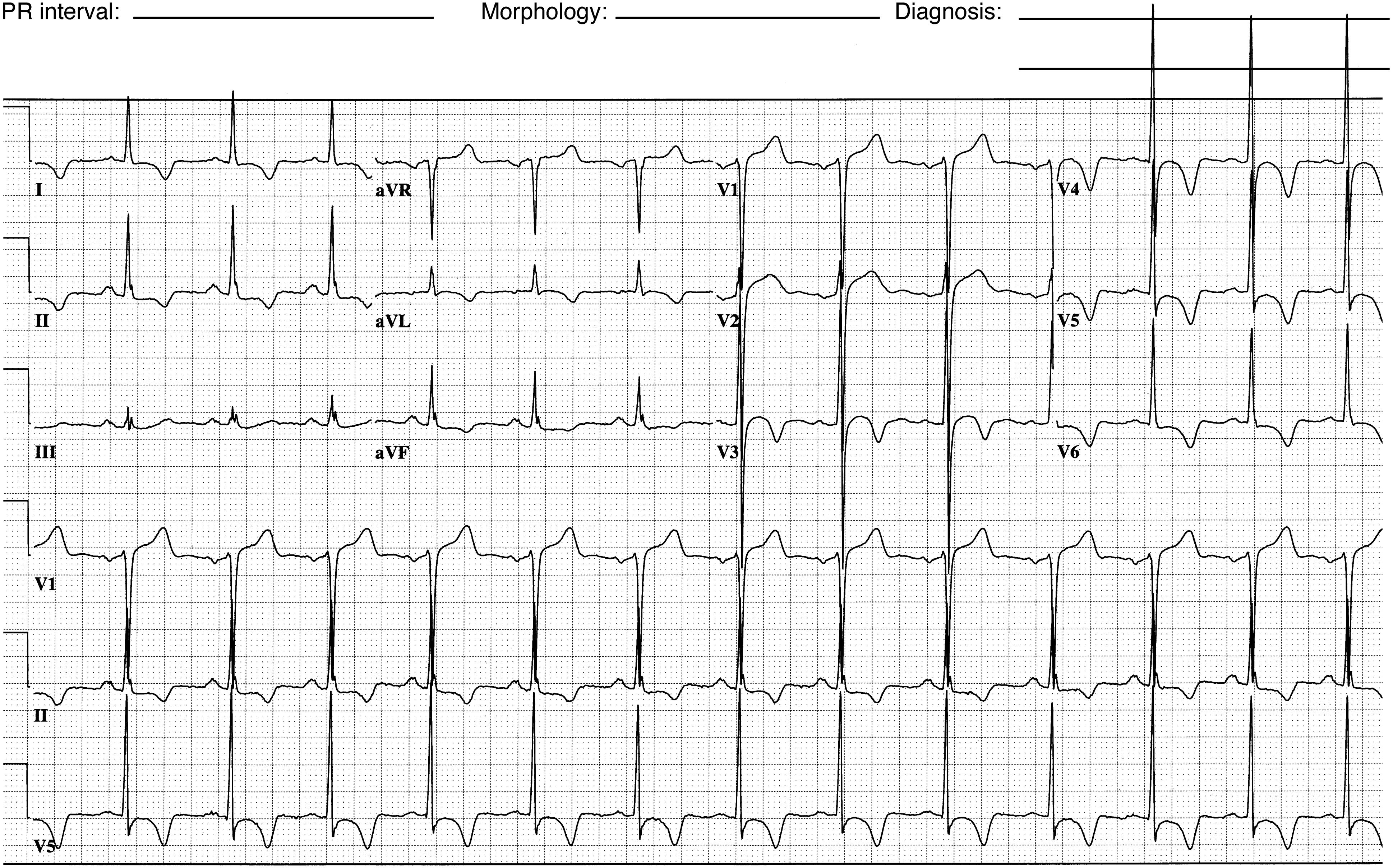
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG Review 43

Atrial rate: __________

Ventricular rate: __________

Rhythm: __________

P wave: __________

PR interval: __________

QRS complex:

Axis: __________

Duration: __________

Voltage: __________

Morphology: __________

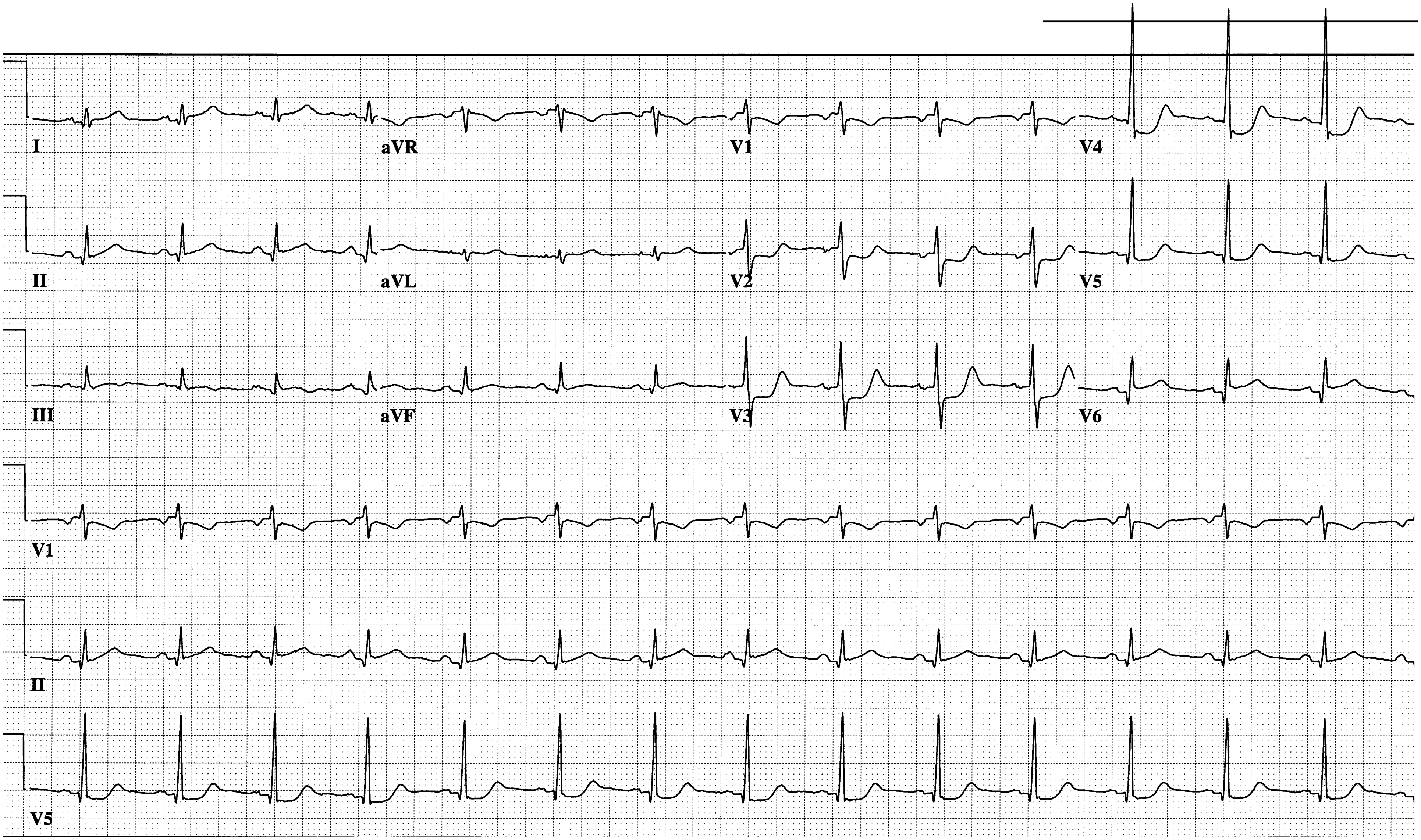
ST segment: __________

T wave: __________

QT interval: __________

U wave: __________

Diagnosis: __________



ECG Review 44

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

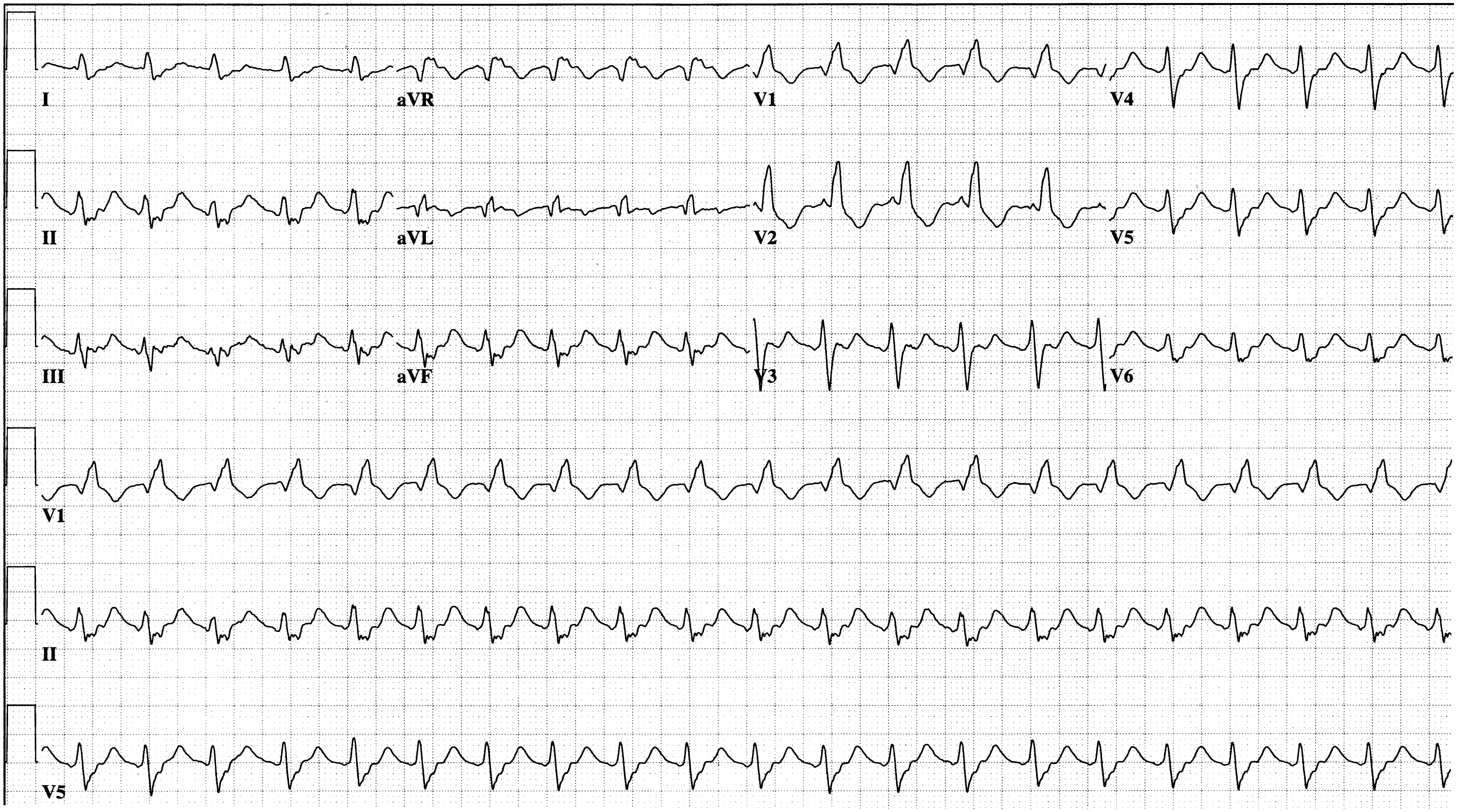
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG Review 45

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

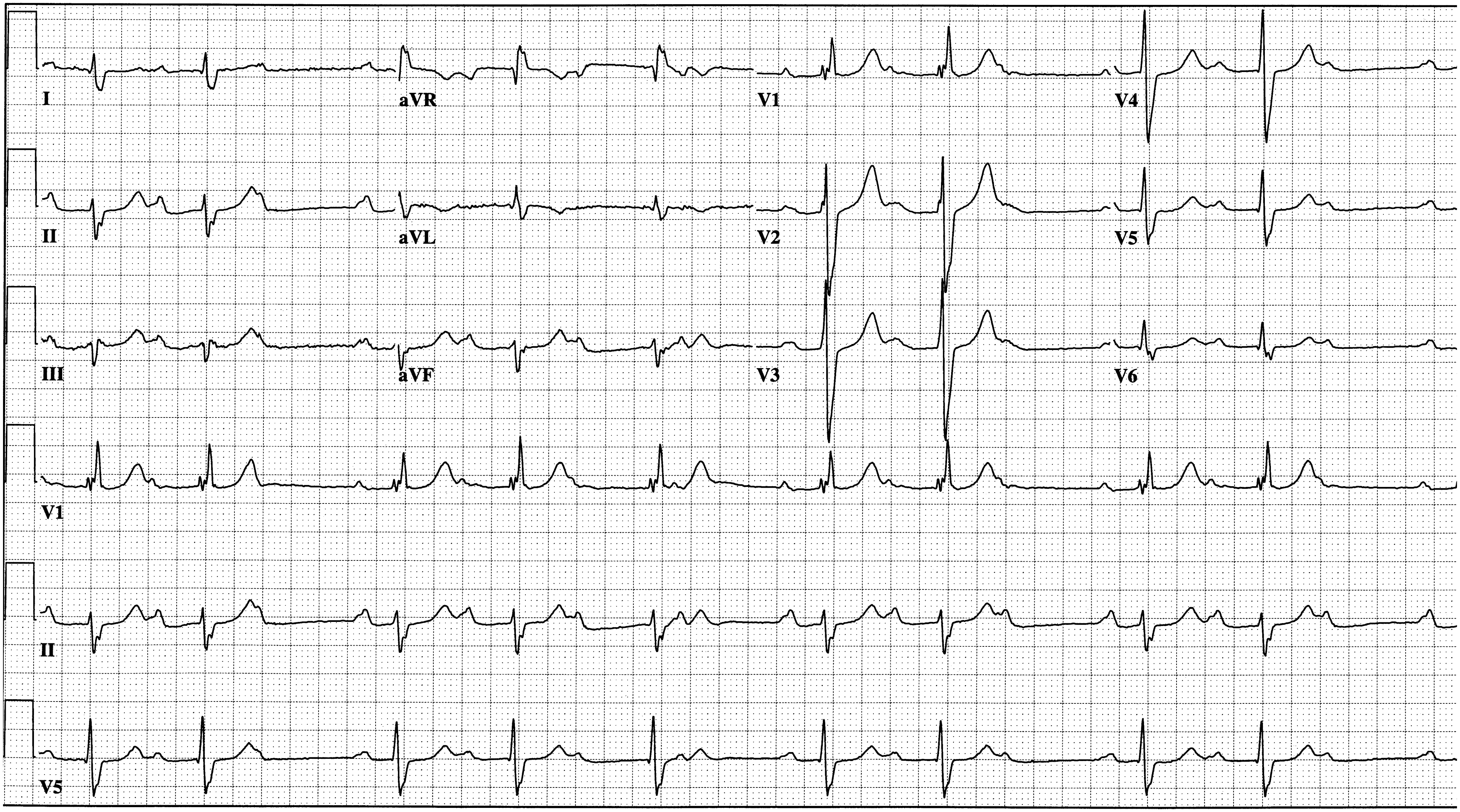
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______

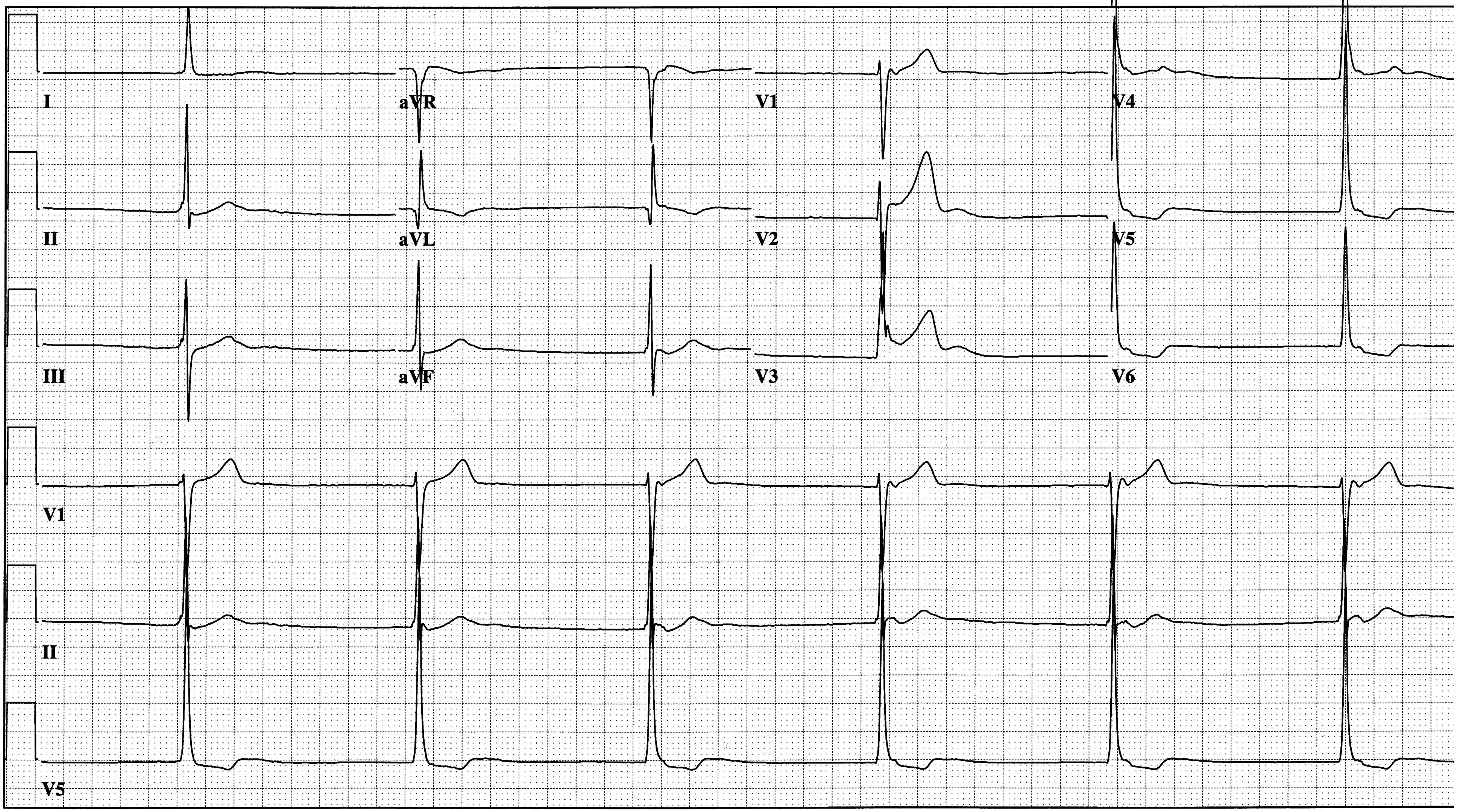


ECG Review 46

Atrial rate: ______
Ventricular rate: ______
Rhythm: ______
P wave: ______
PR interval: ______

QRS complex:
Axis: ______
Duration: ______
Voltage: ______
Morphology: ______

ST segment: ______
T wave: ______
QT interval: ______
U wave: ______
Diagnosis: ______



ECG Review 47

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

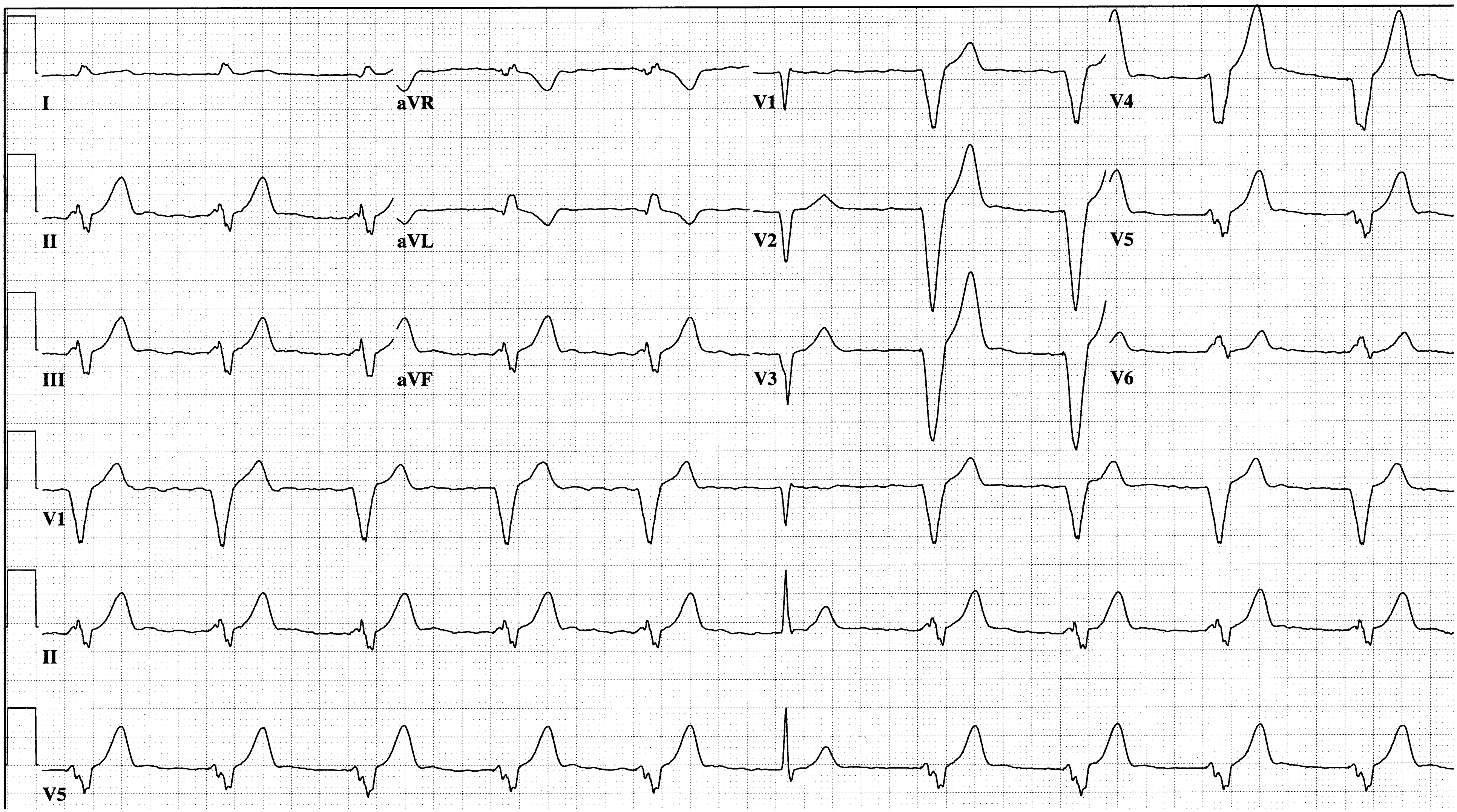
ST segment: ______

T wave: ______

QT interval: ______

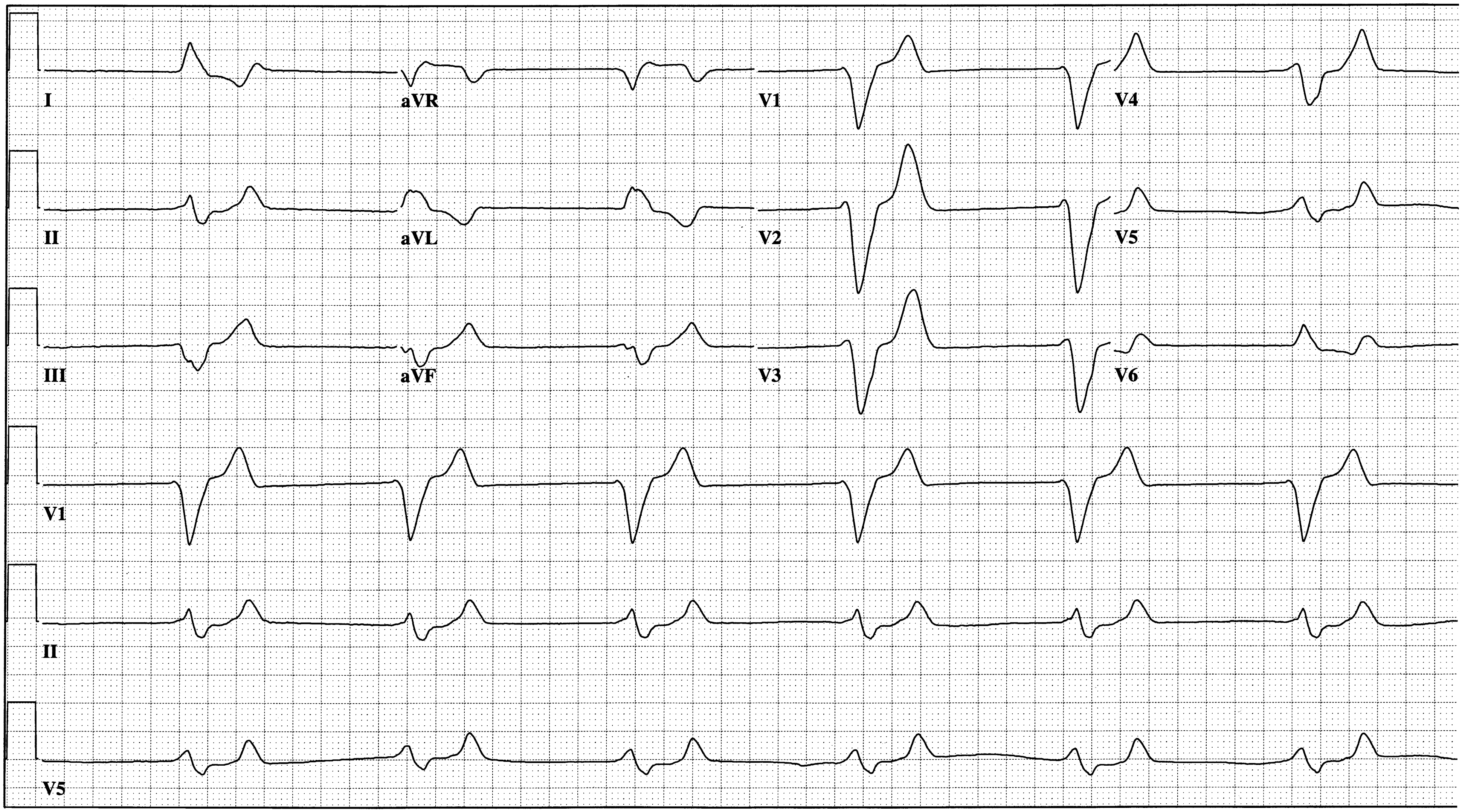
U wave: ______

Diagnosis: ______



ECG Review 48

Atrial rate:	QRS complex:	ST segment:
Ventricular rate:	Axis:	T wave:
Rhythm:	Duration:	QT interval:
P wave:	Voltage:	U wave:
PR interval:	Morphology:	Diagnosis:



ECG Review 49

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

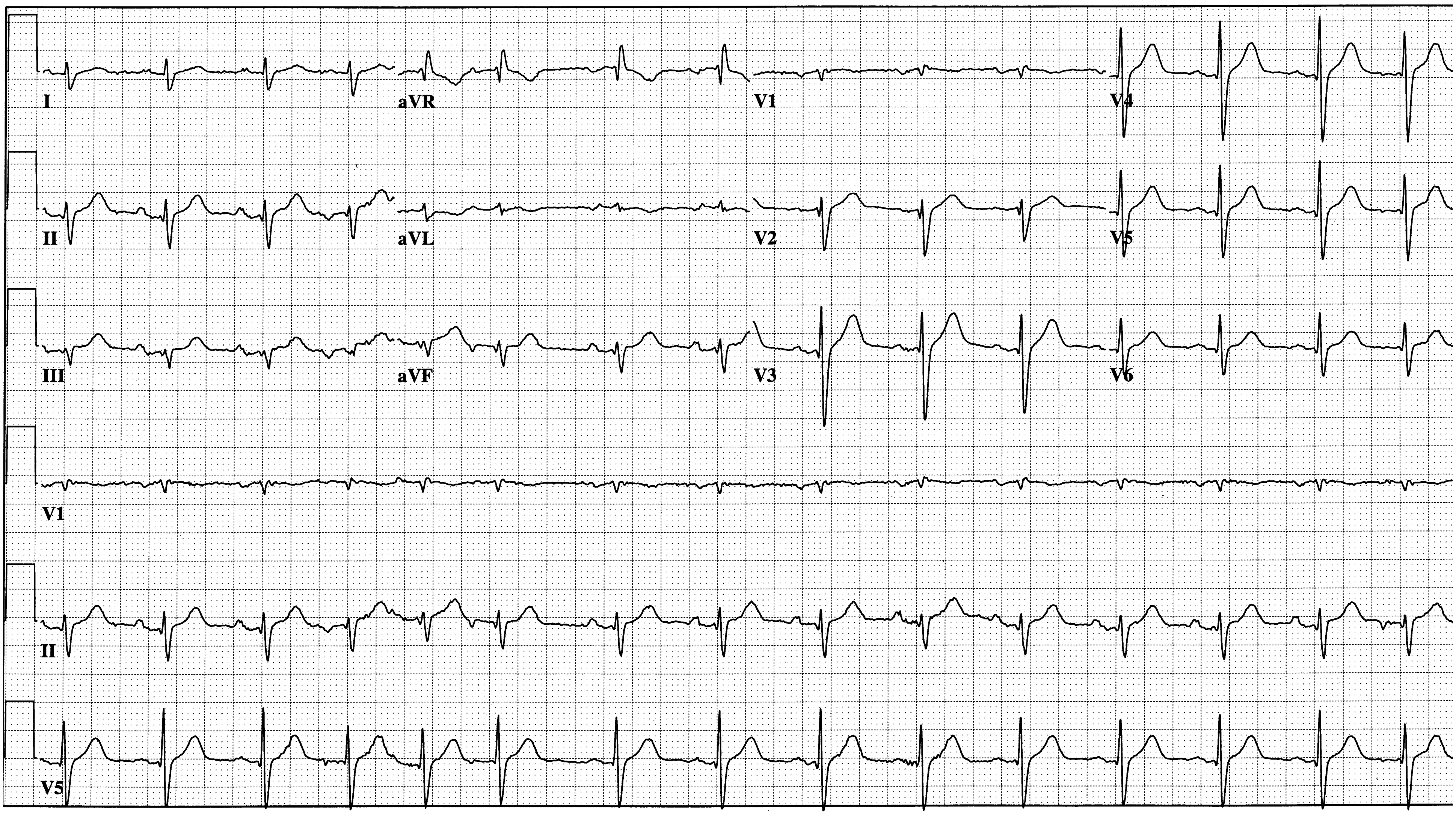
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG Review 50

Atrial rate: ____________

Ventricular rate: ____________

Rhythm: ____________

P wave: ____________

PR interval: ____________

QRS complex:

Axis: ____________

Duration: ____________

Voltage: ____________

Morphology: ____________

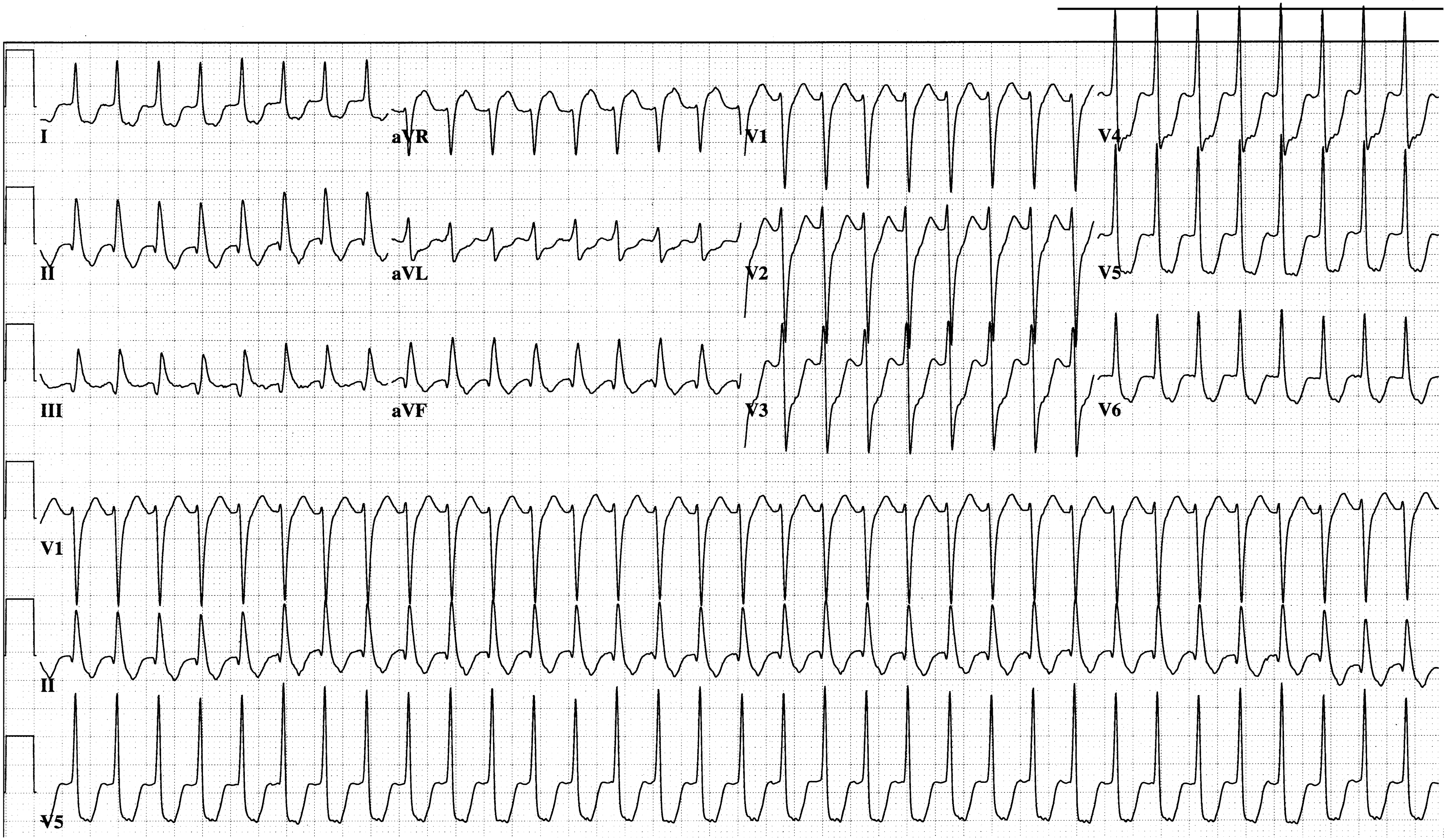
ST segment: ____________

T wave: ____________

QT interval: ____________

U wave: ____________

Diagnosis: ____________



ECG Review 51

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

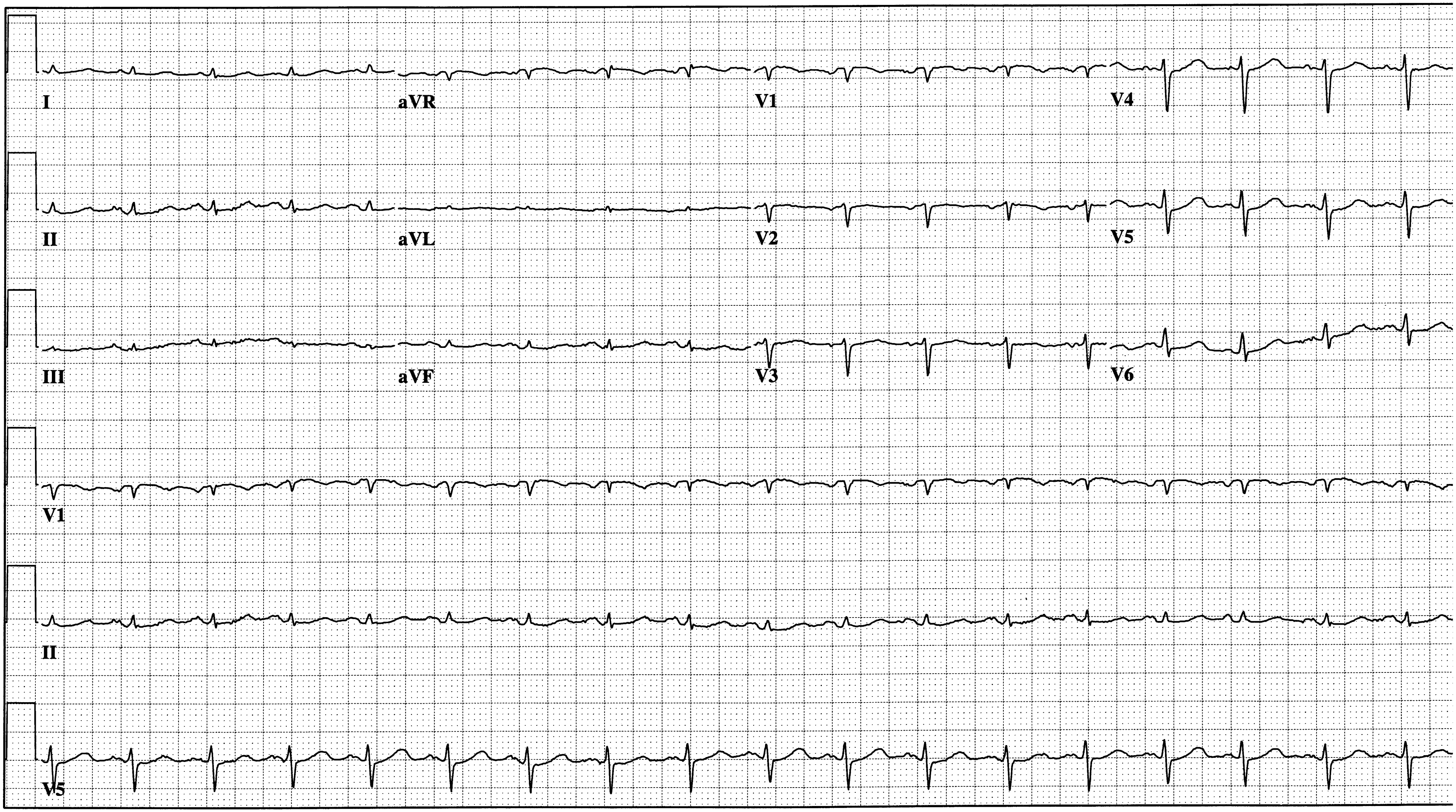
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG Review 52

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

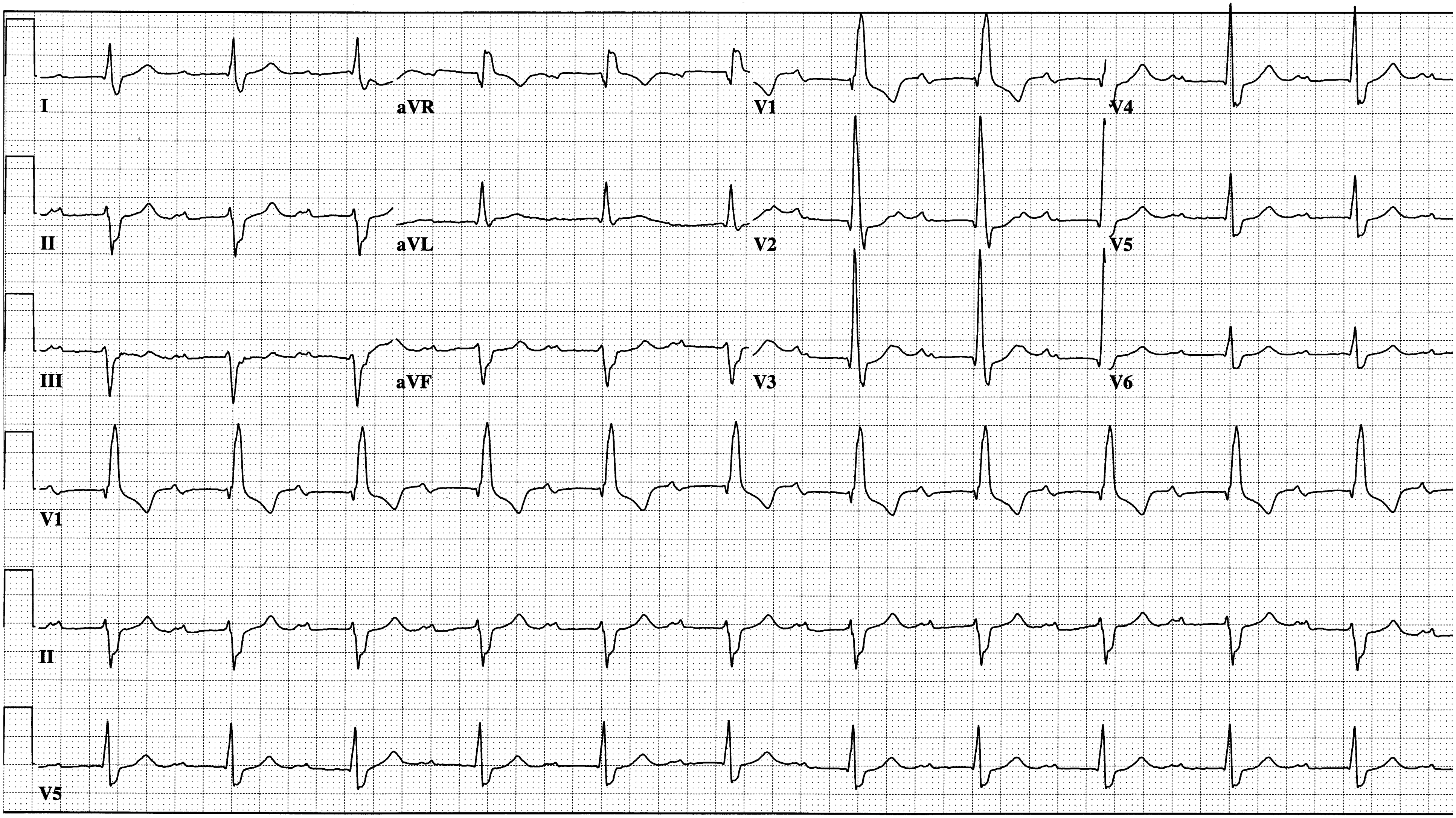
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG Review 53

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

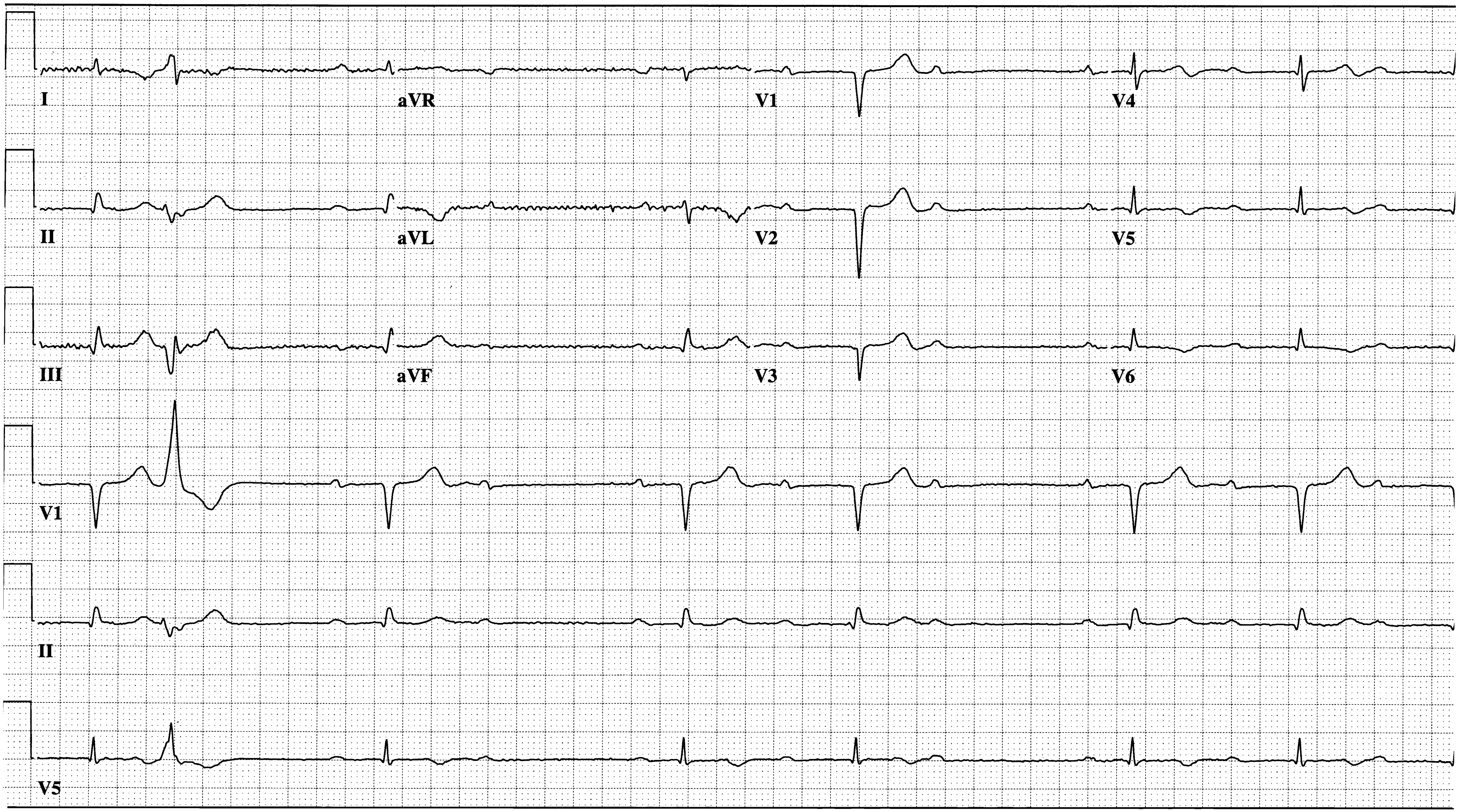
ST segment: ______

T wave: ______

QT interval: ______

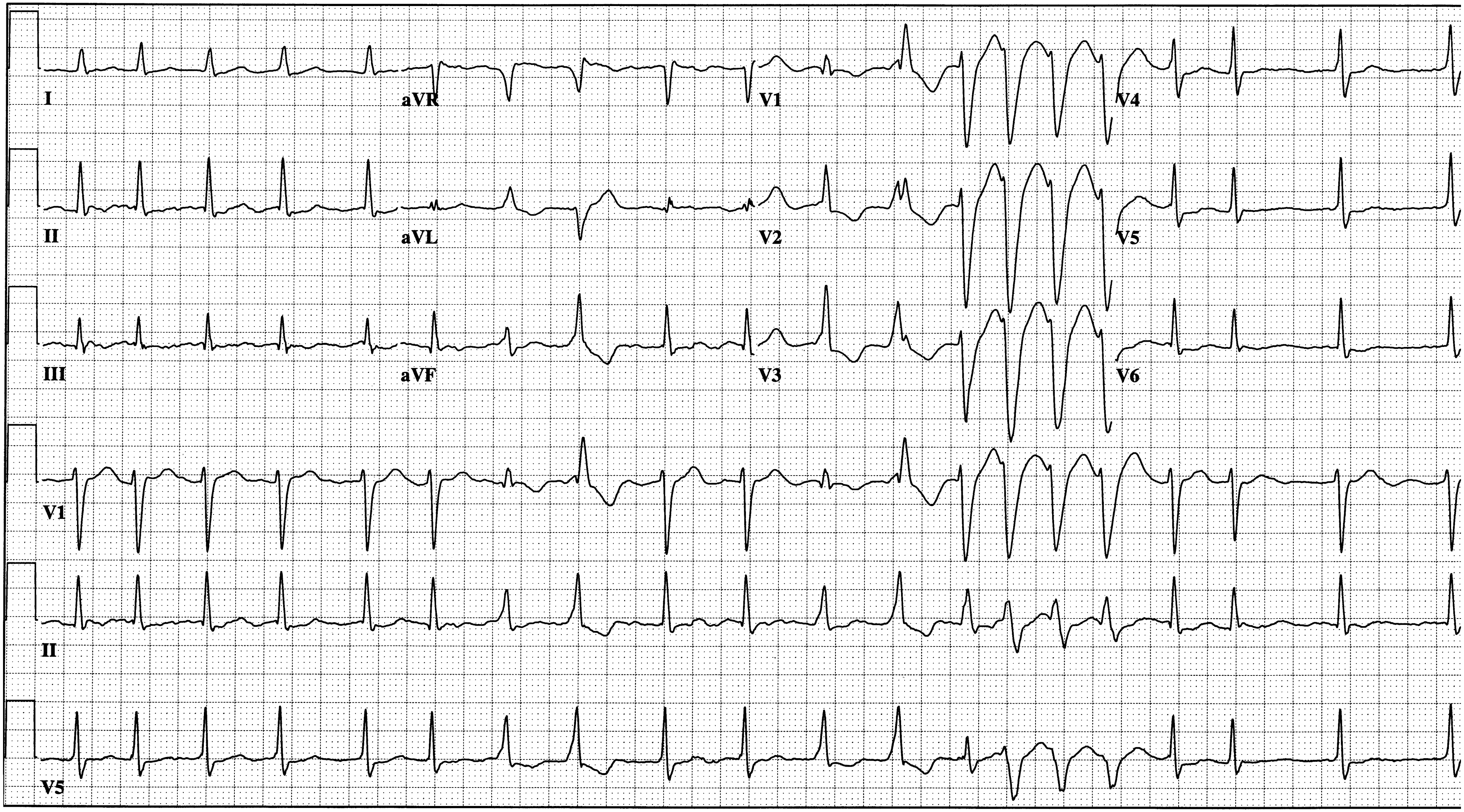
U wave: ______

Diagnosis: ______



ECG Review 54

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG Review 55

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

ST segment: ____________________

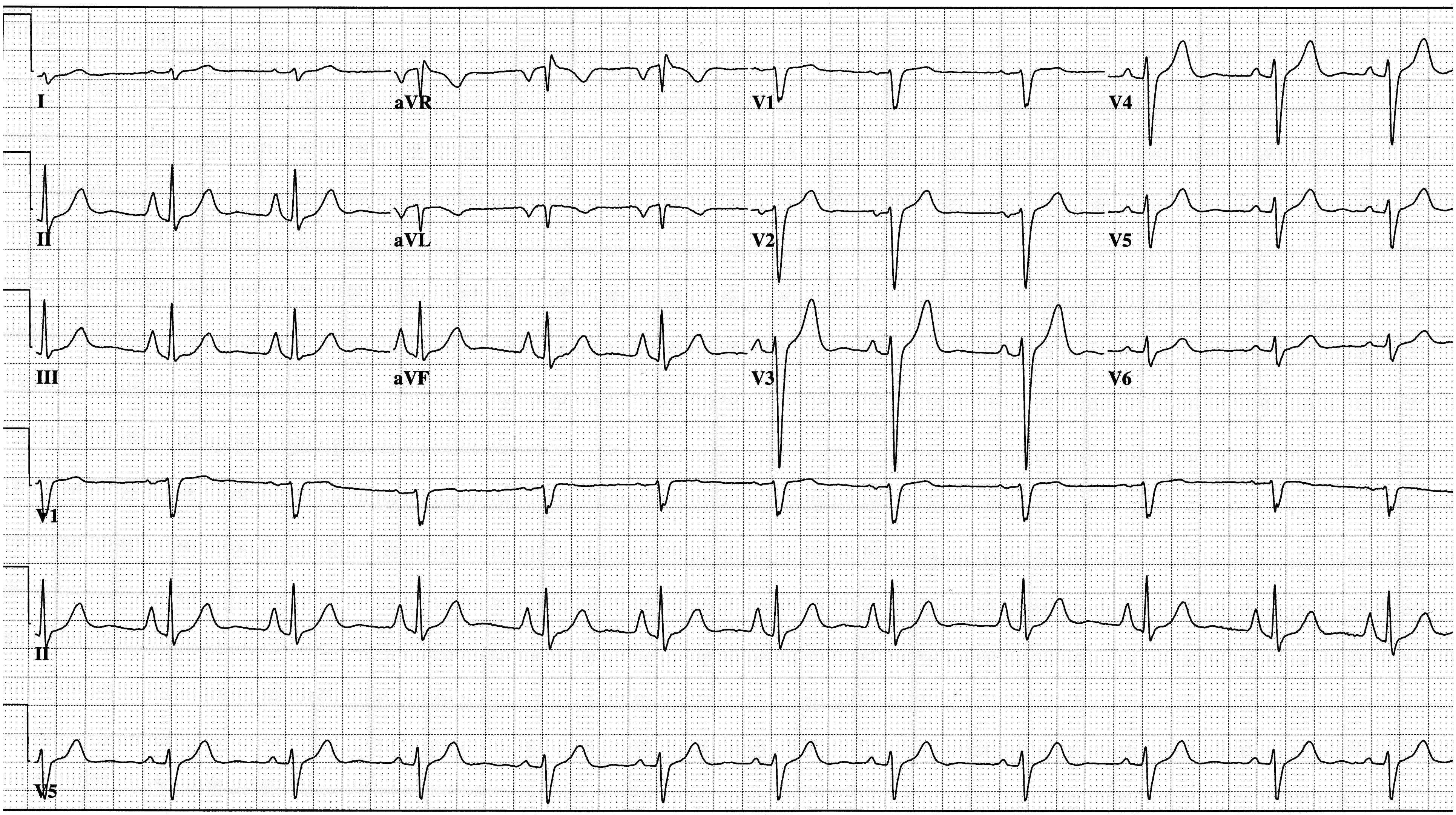
T wave: ____________________

QT interval: ____________________

U wave: ____________________

Diagnosis: ____________________

____



ECG Review 56

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

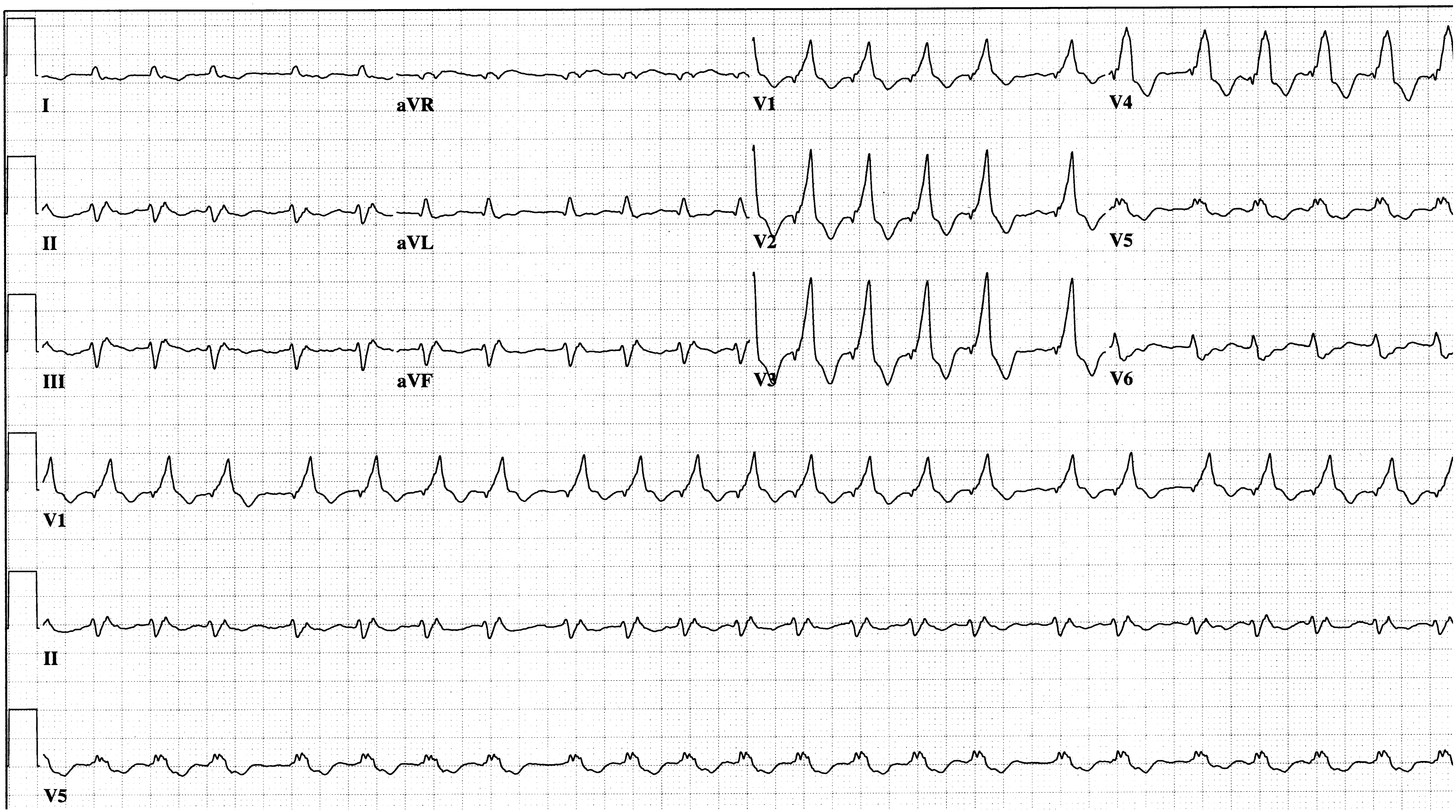
T wave: ______________________

QT interval: ______________________

U wave: ______________________

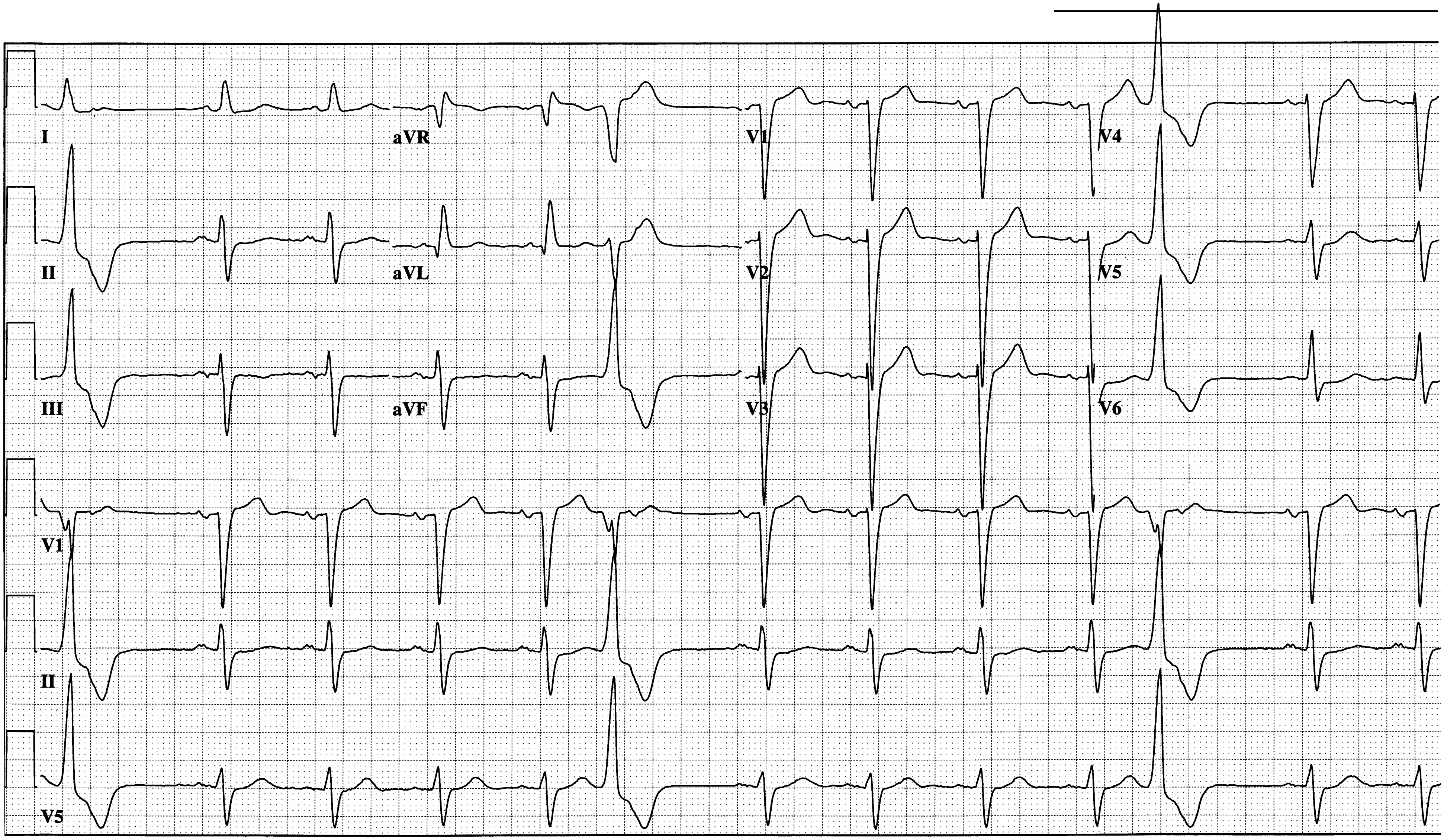
Diagnosis: ______________________

____



ECG Review 57

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG Review 58

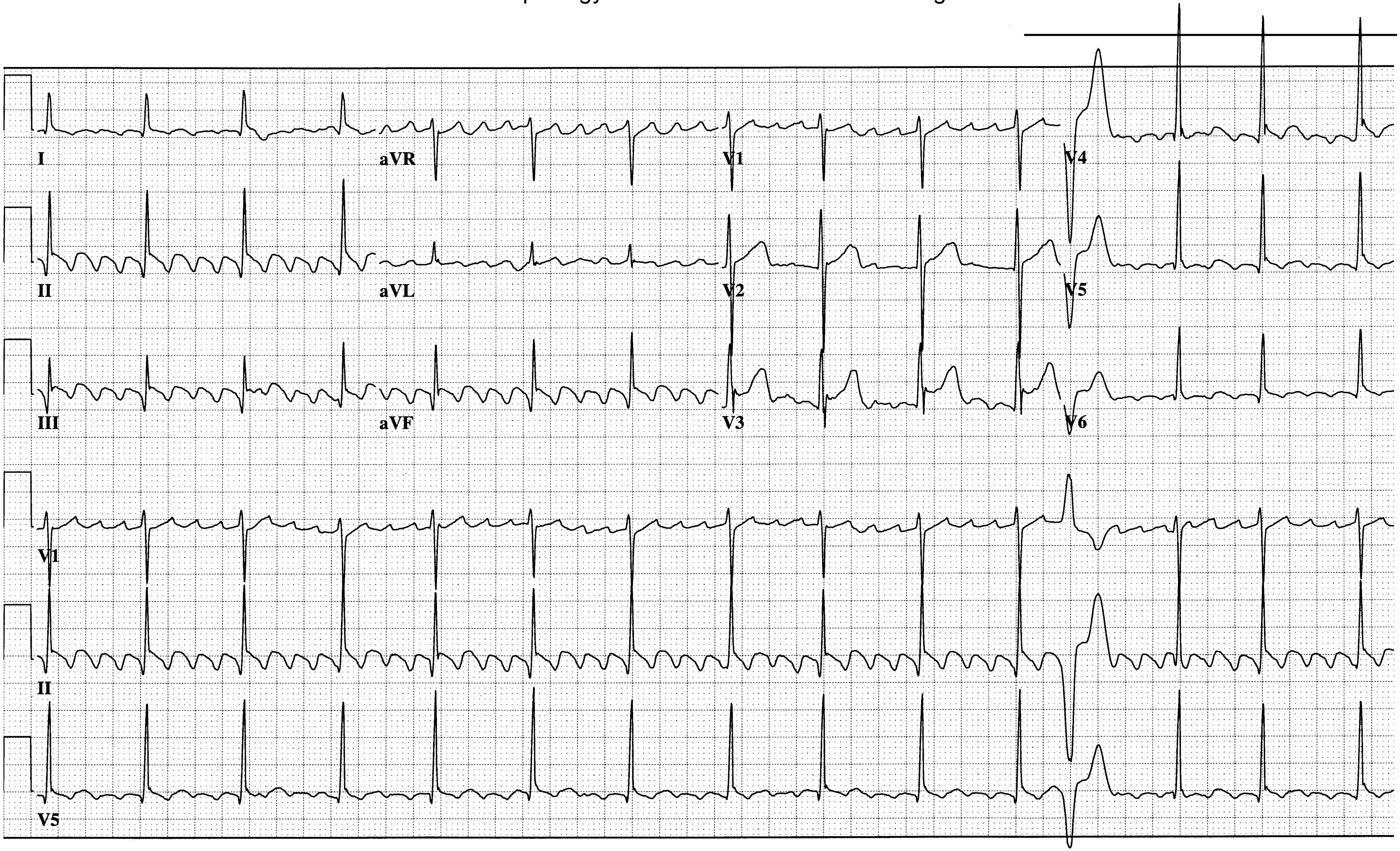
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

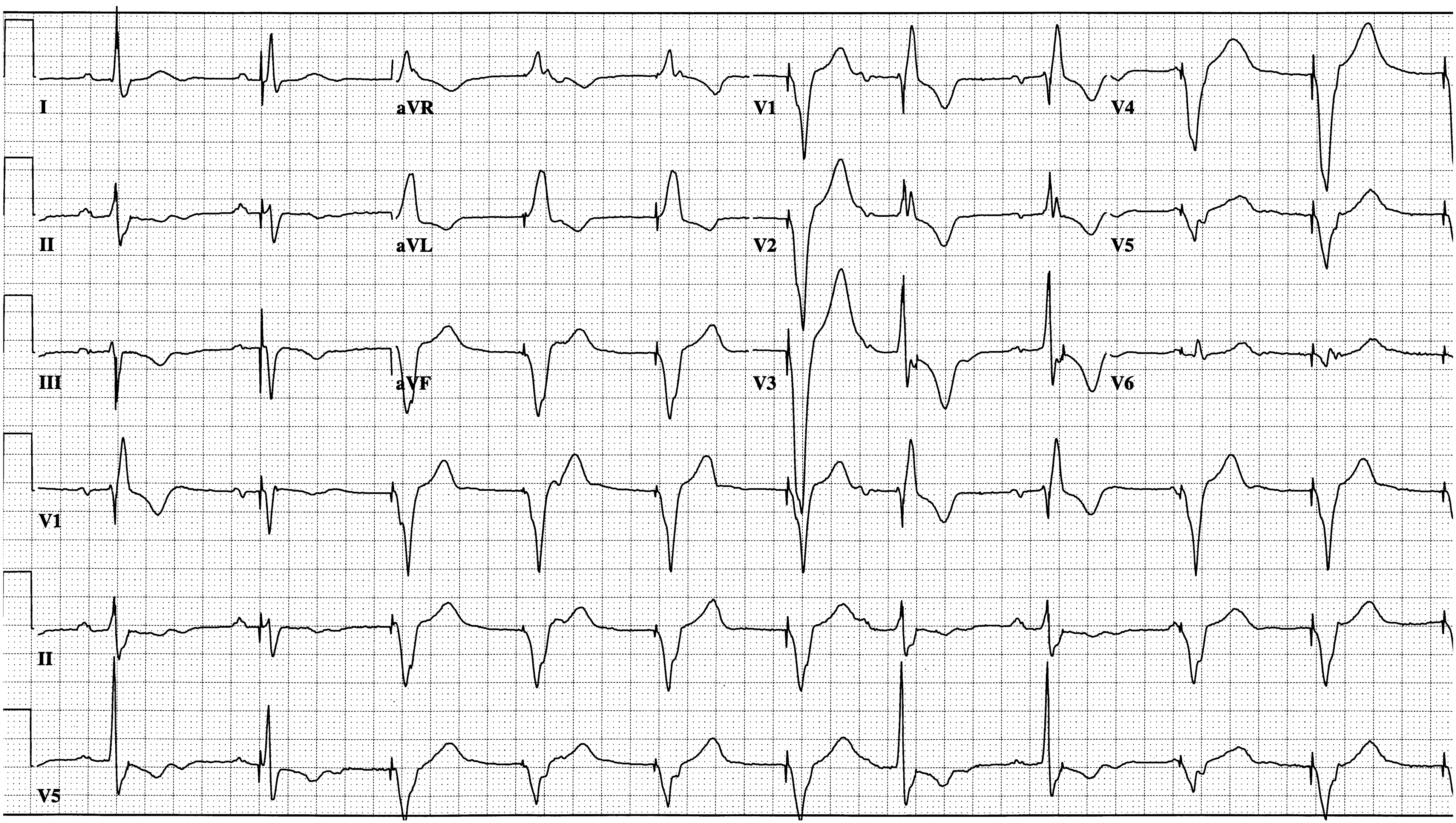
P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG Review 59

Atrial rate:	QRS complex:	ST segment:
Ventricular rate:	Axis:	T wave:
Rhythm:	Duration:	QT interval:
P wave:	Voltage:	U wave:
PR interval:	Morphology:	Diagnosis:



ECG Review 60

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

ST segment: ____________________

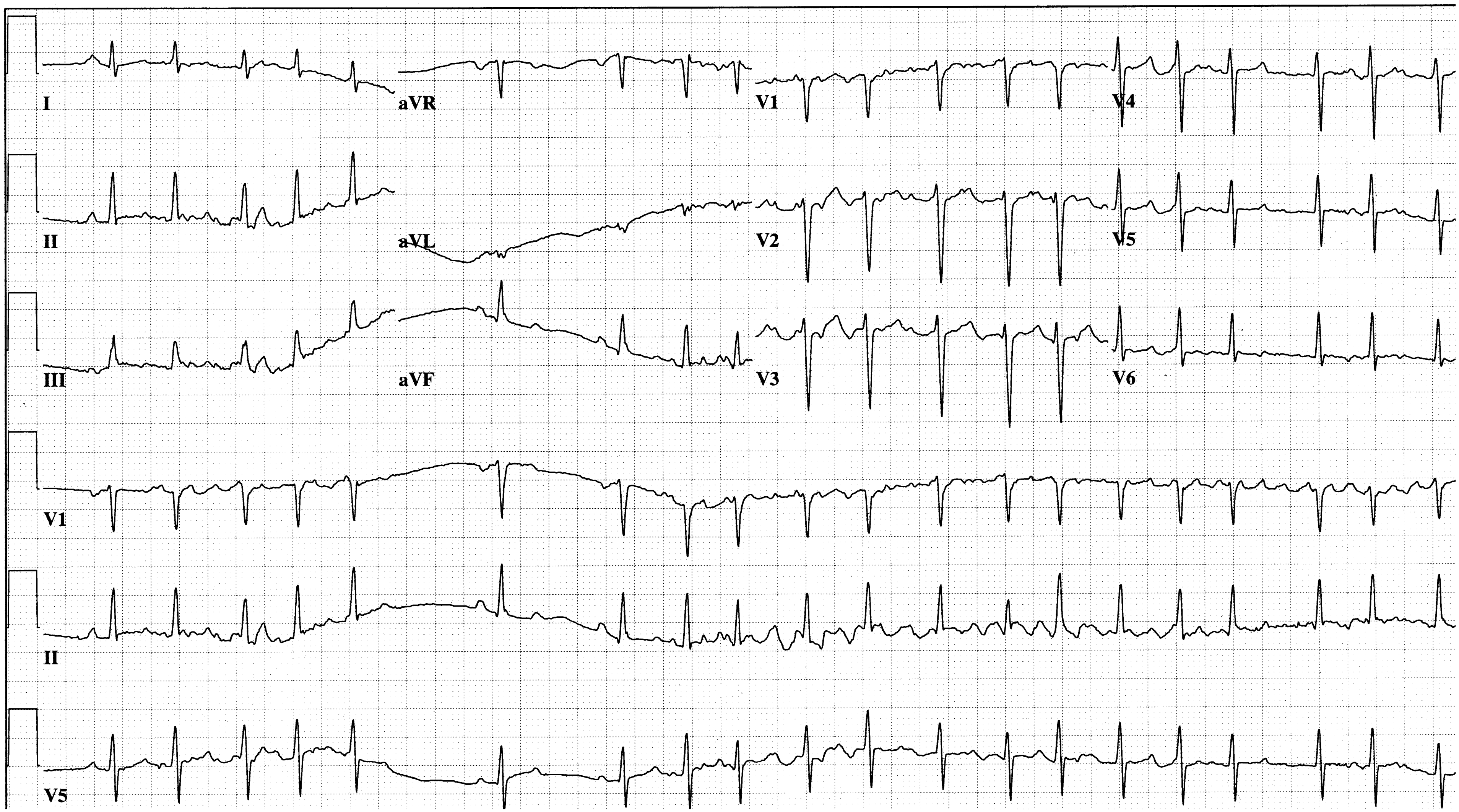
T wave: ____________________

QT interval: ____________________

U wave: ____________________

Diagnosis: ____________________

____



ECG Review 61

Atrial rate: ____________

Ventricular rate: ____________

Rhythm: ____________

P wave: ____________

PR interval: ____________

QRS complex:

Axis: ____________

Duration: ____________

Voltage: ____________

Morphology: ____________

ST segment: ____________

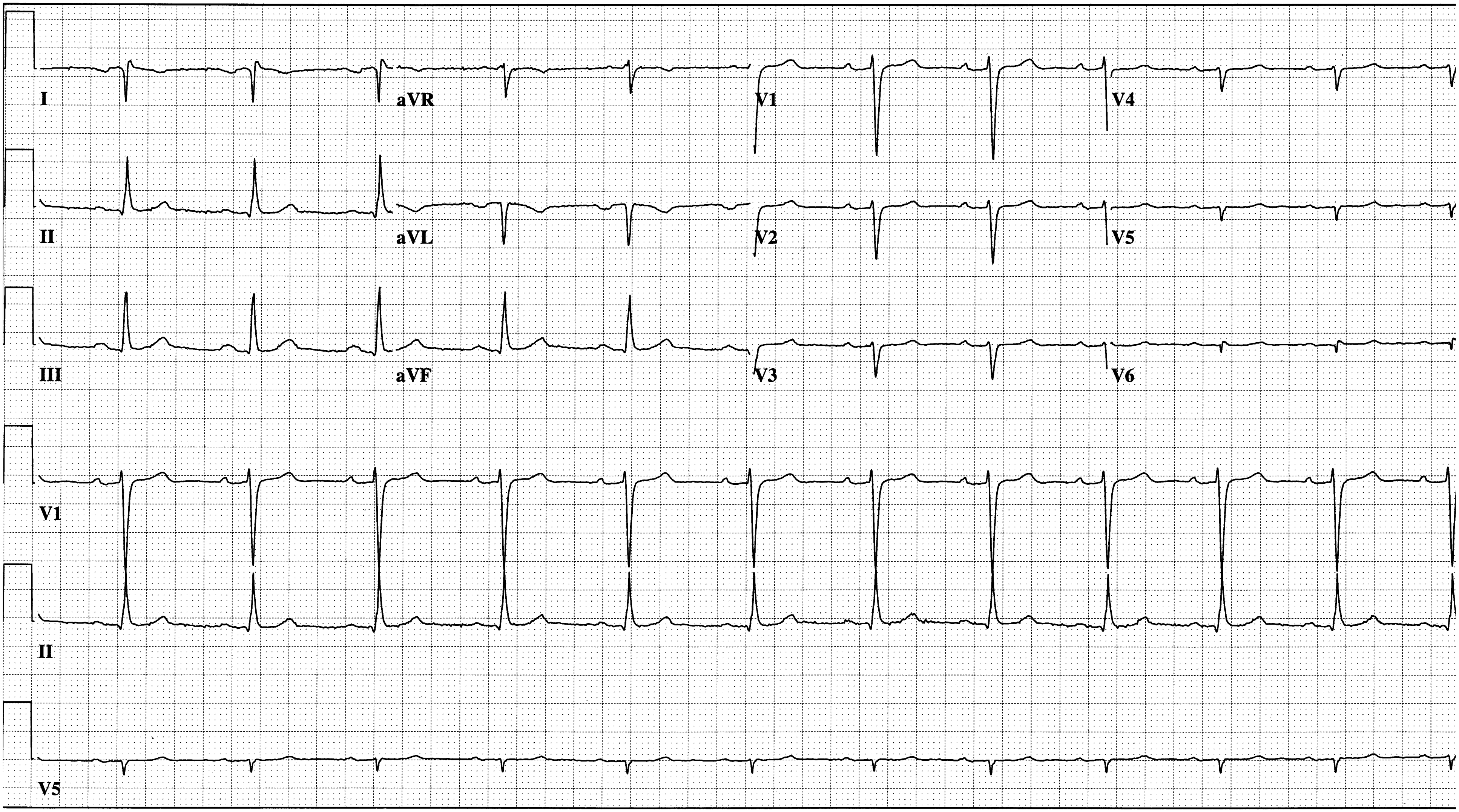
T wave: ____________

QT interval: ____________

U wave: ____________

Diagnosis: ____________

____



ECG Review 62

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

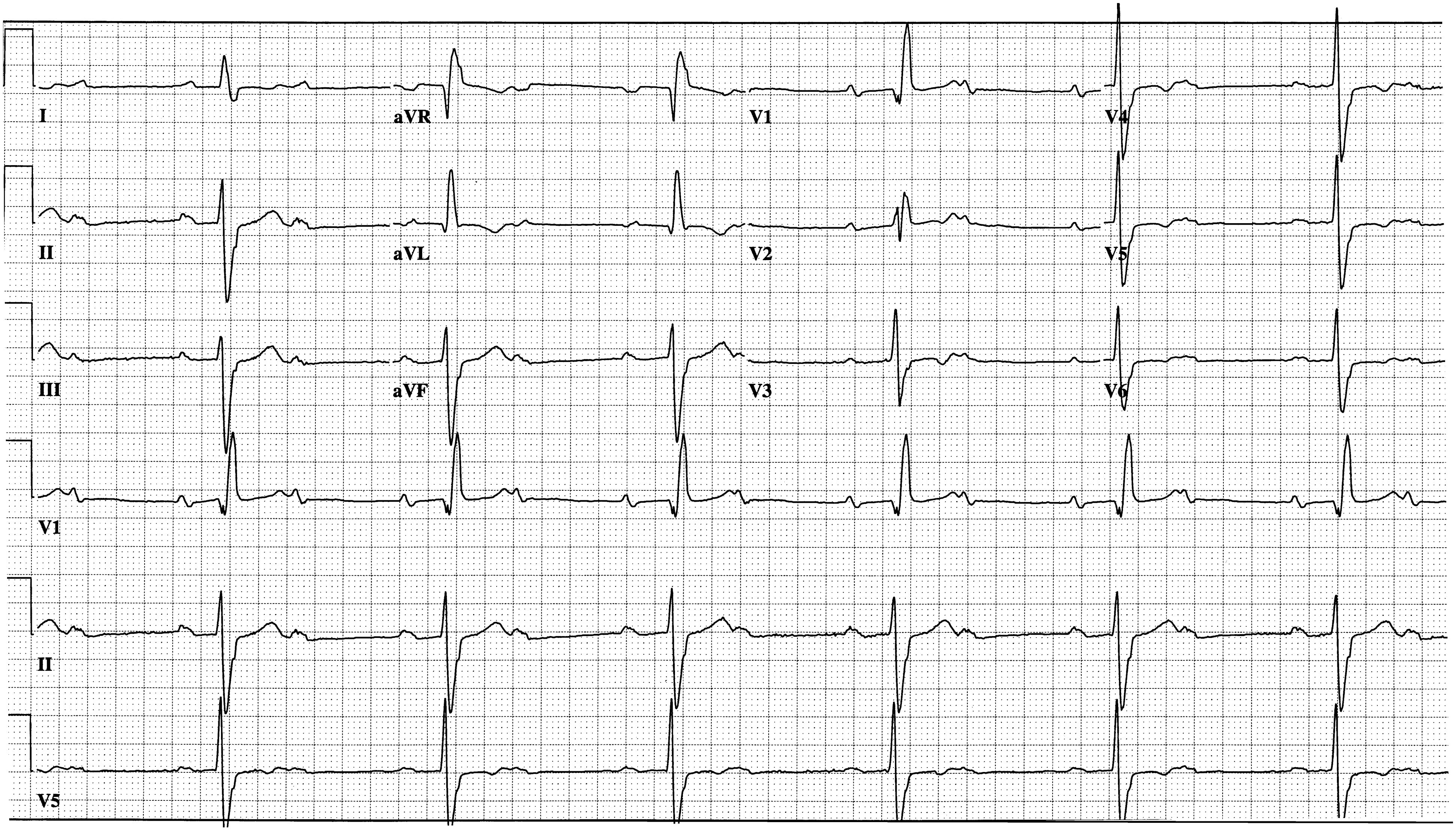
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG Review 63

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

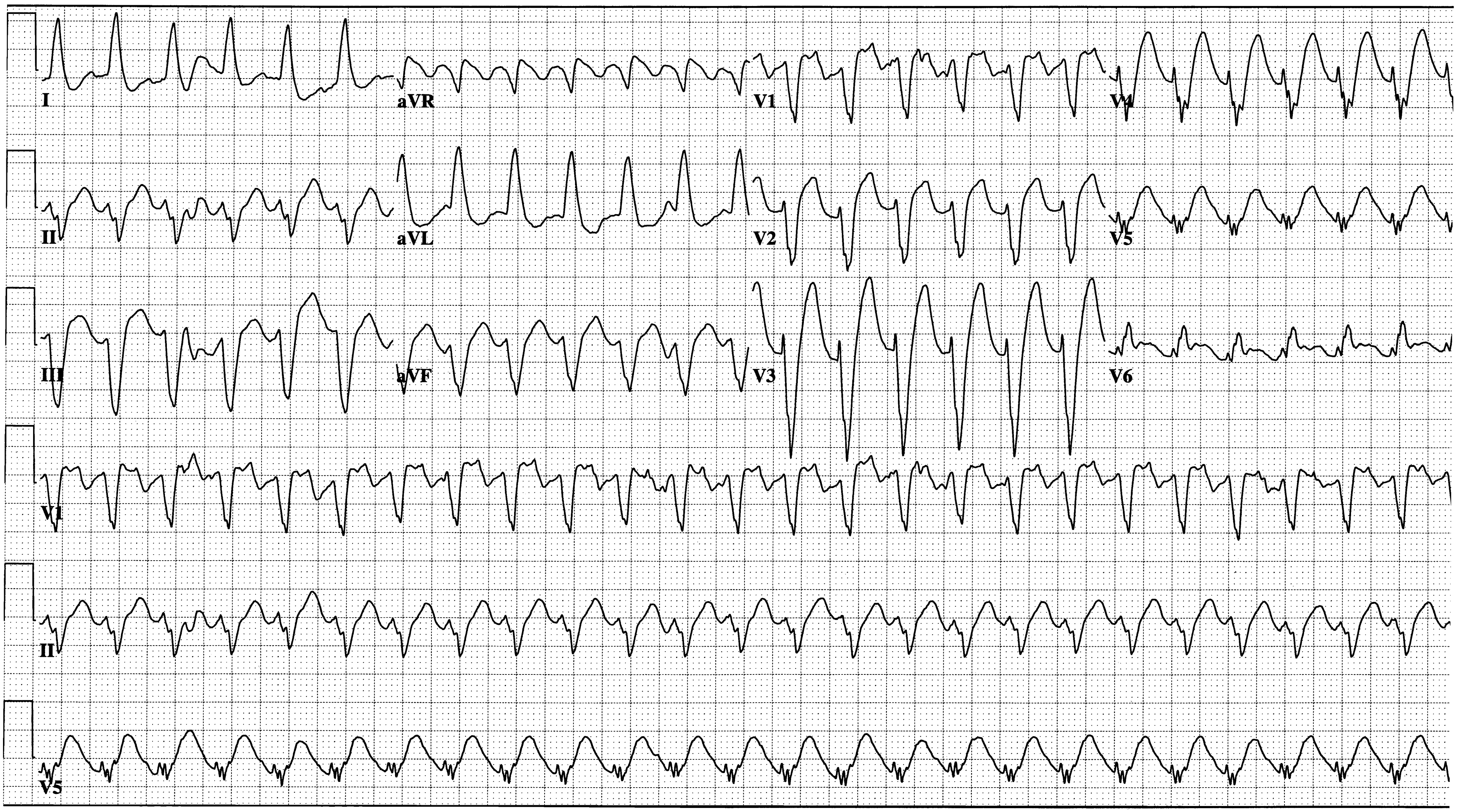
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG Review 64

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

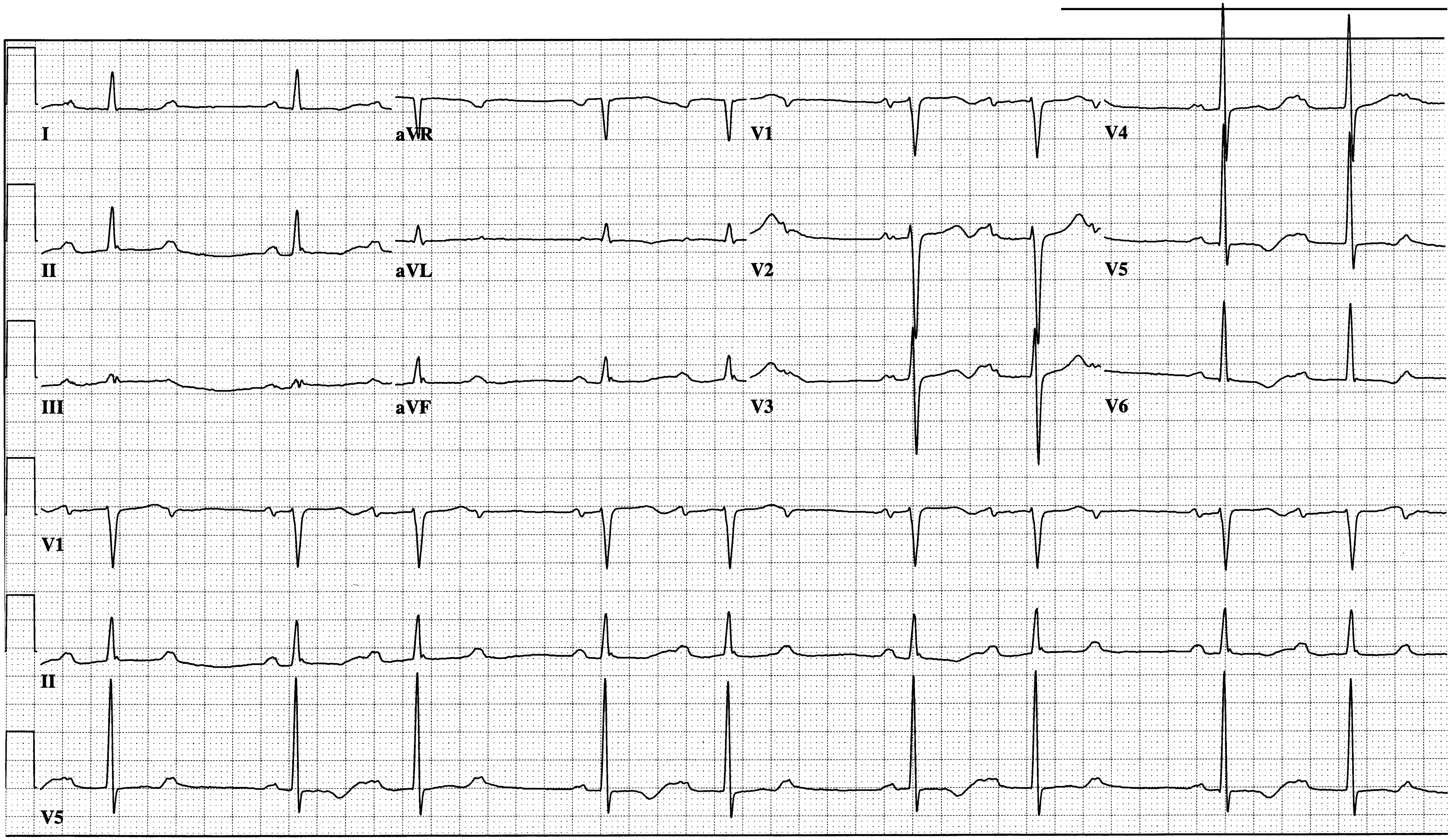
ST segment: ______________________

T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________



ECG Review 65

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

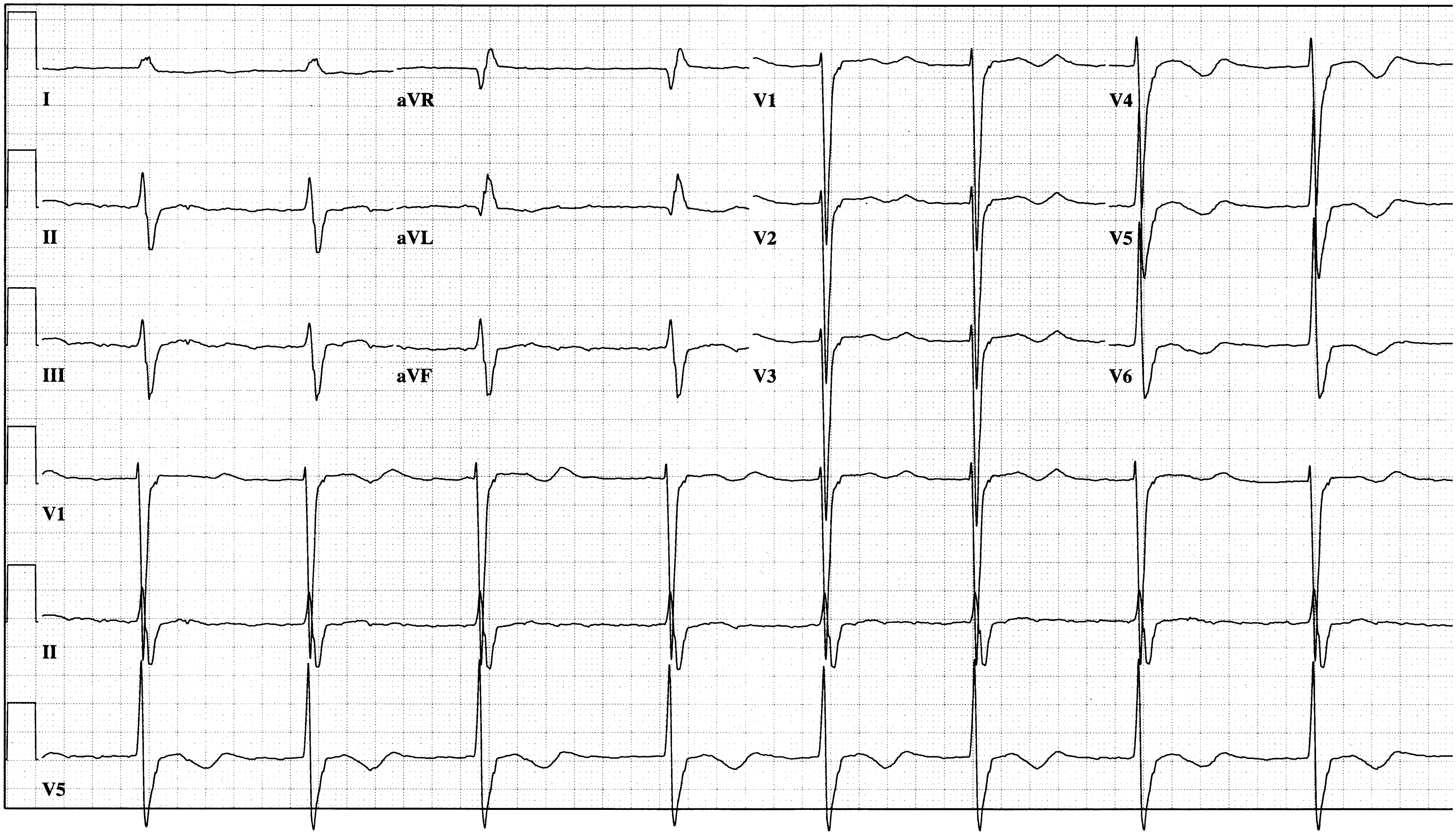
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG Review 66

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

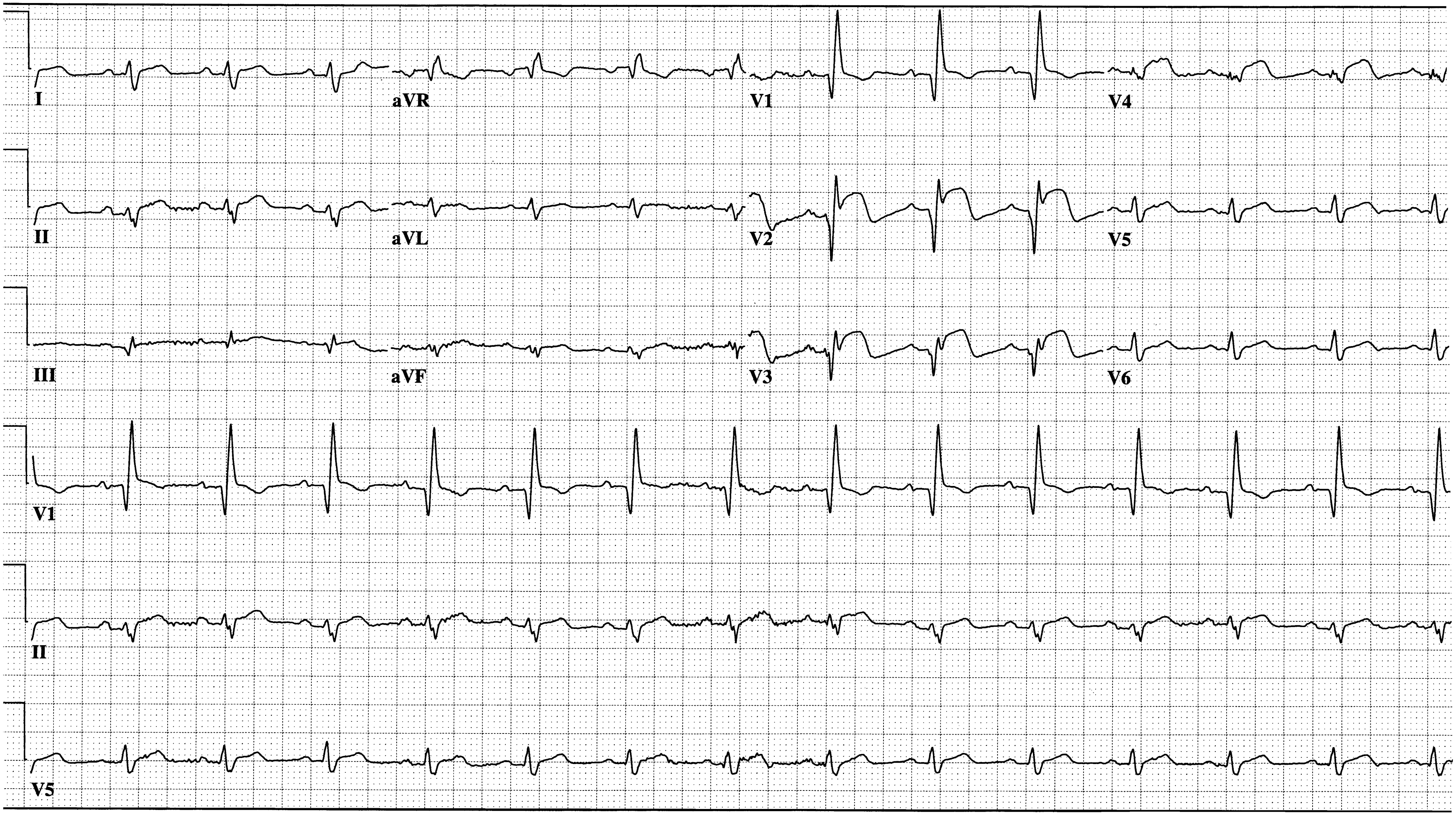
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG Review 67

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

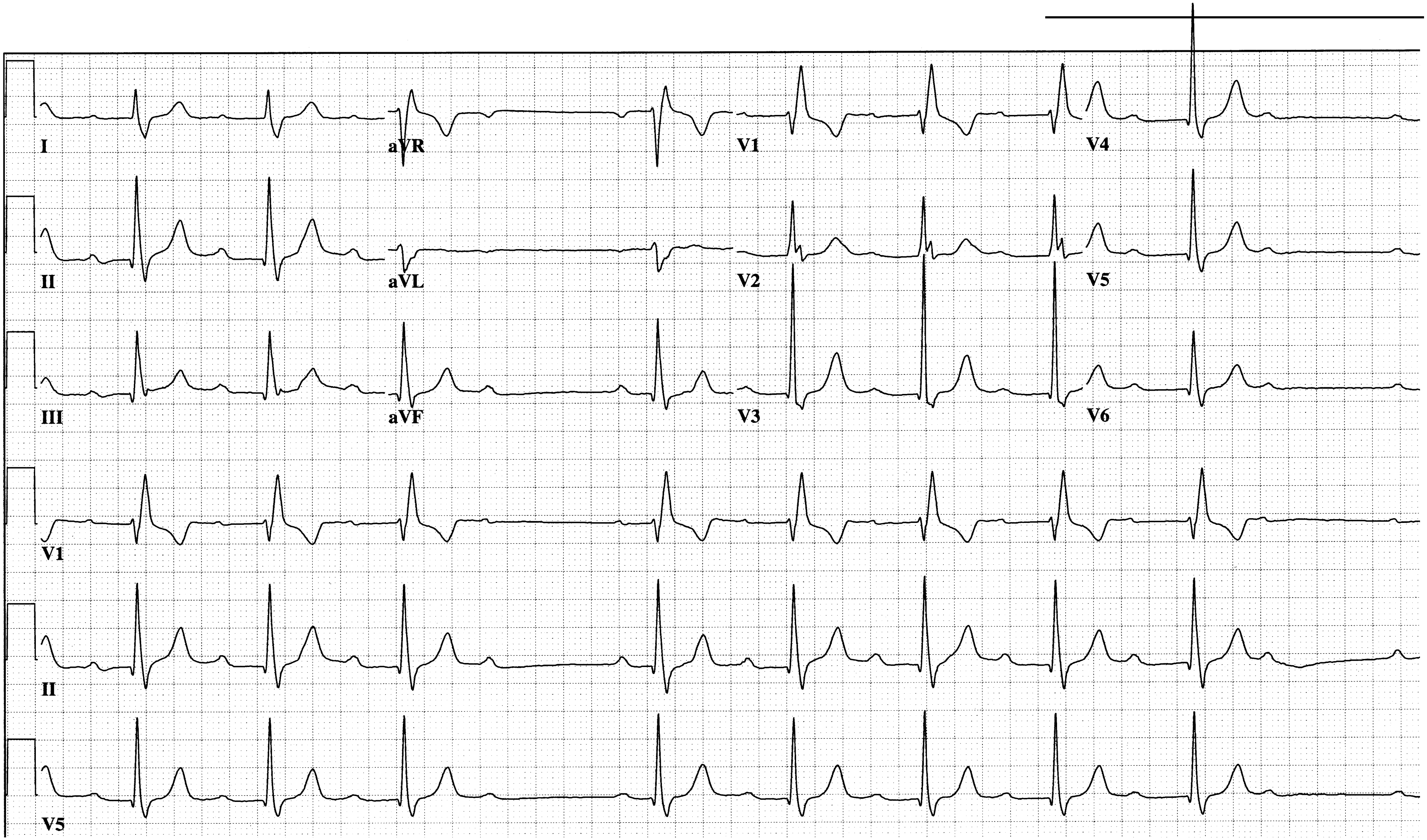
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG Review 68

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

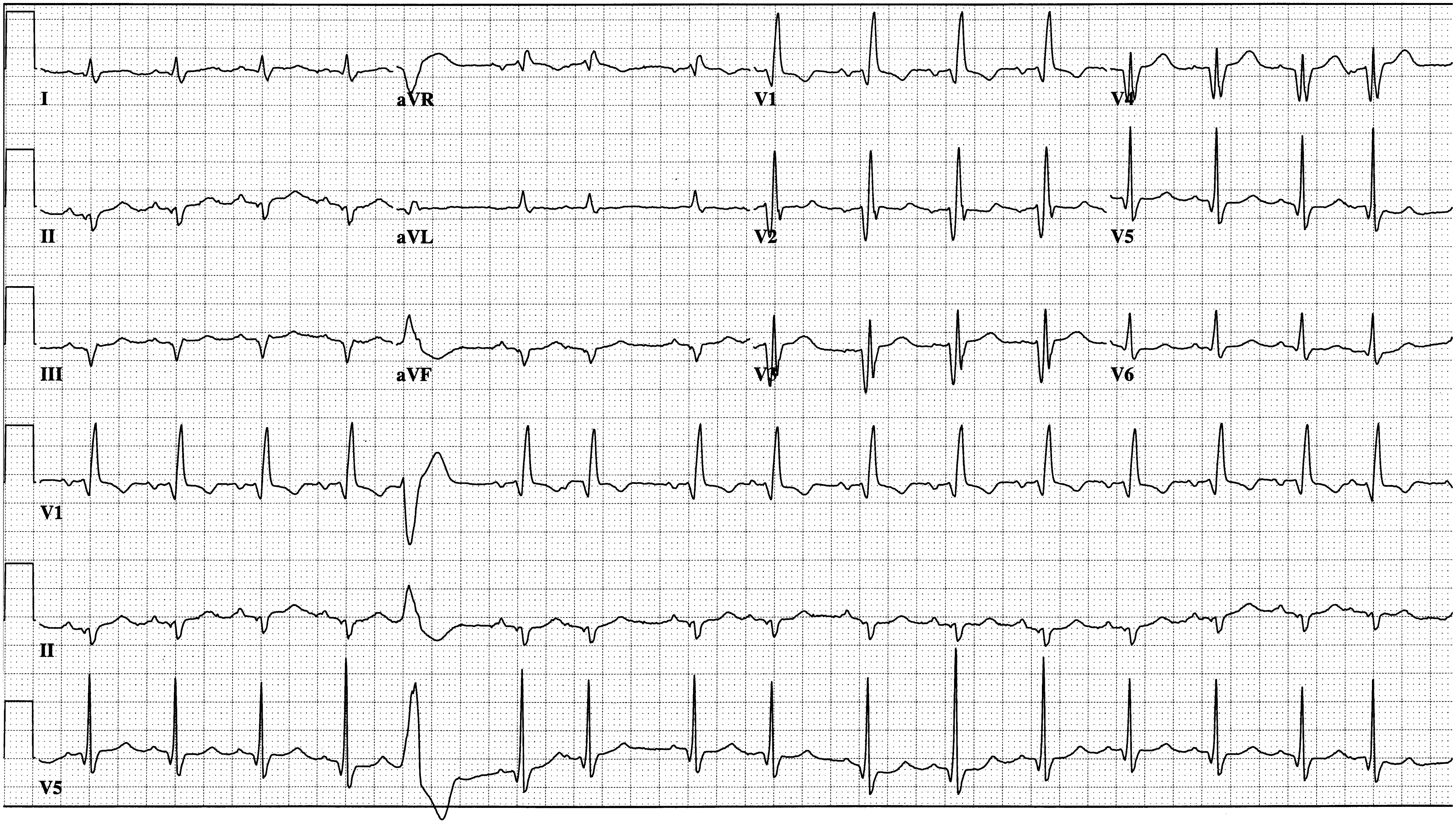
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG Review 69

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

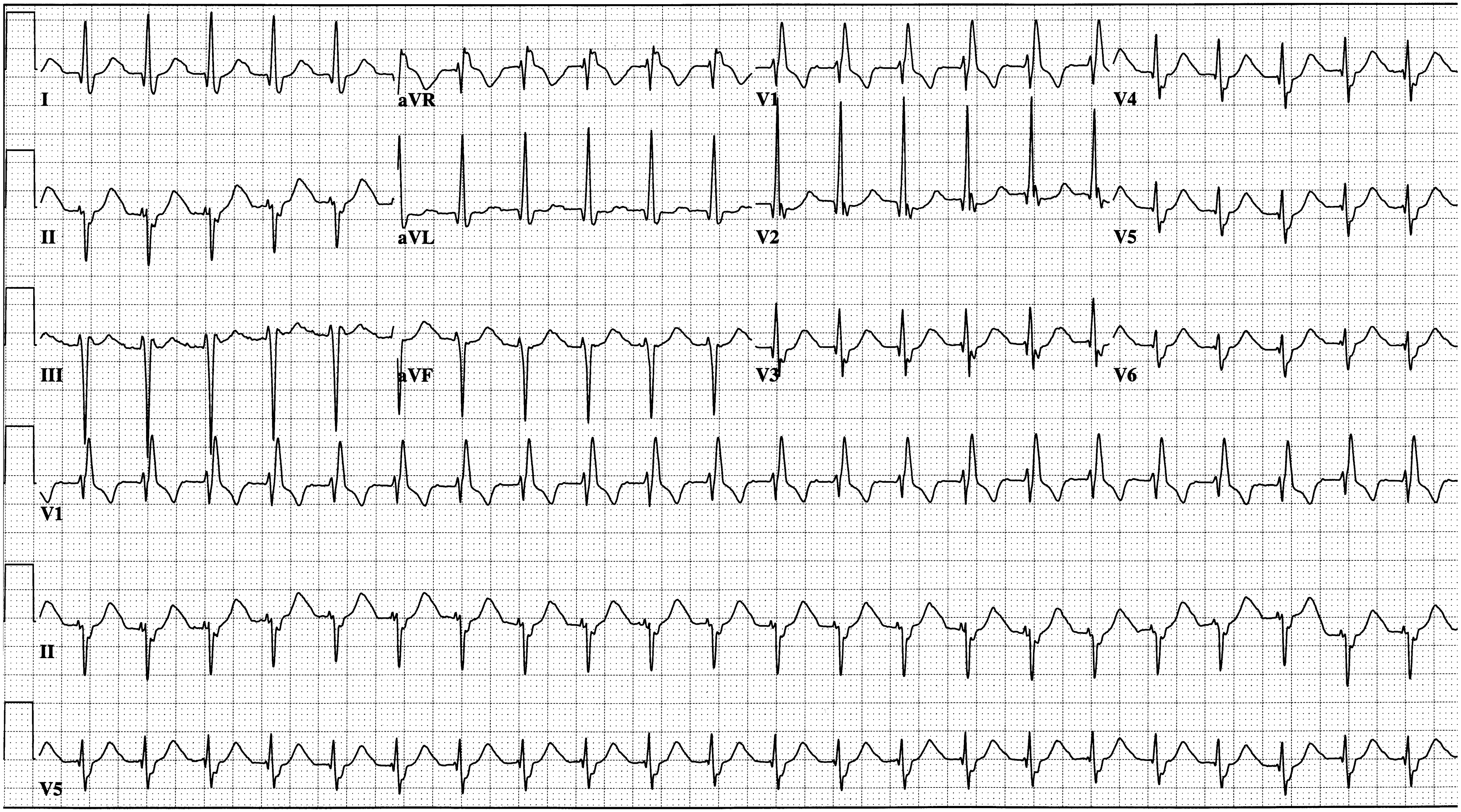
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG Review 70

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

ST segment: ______

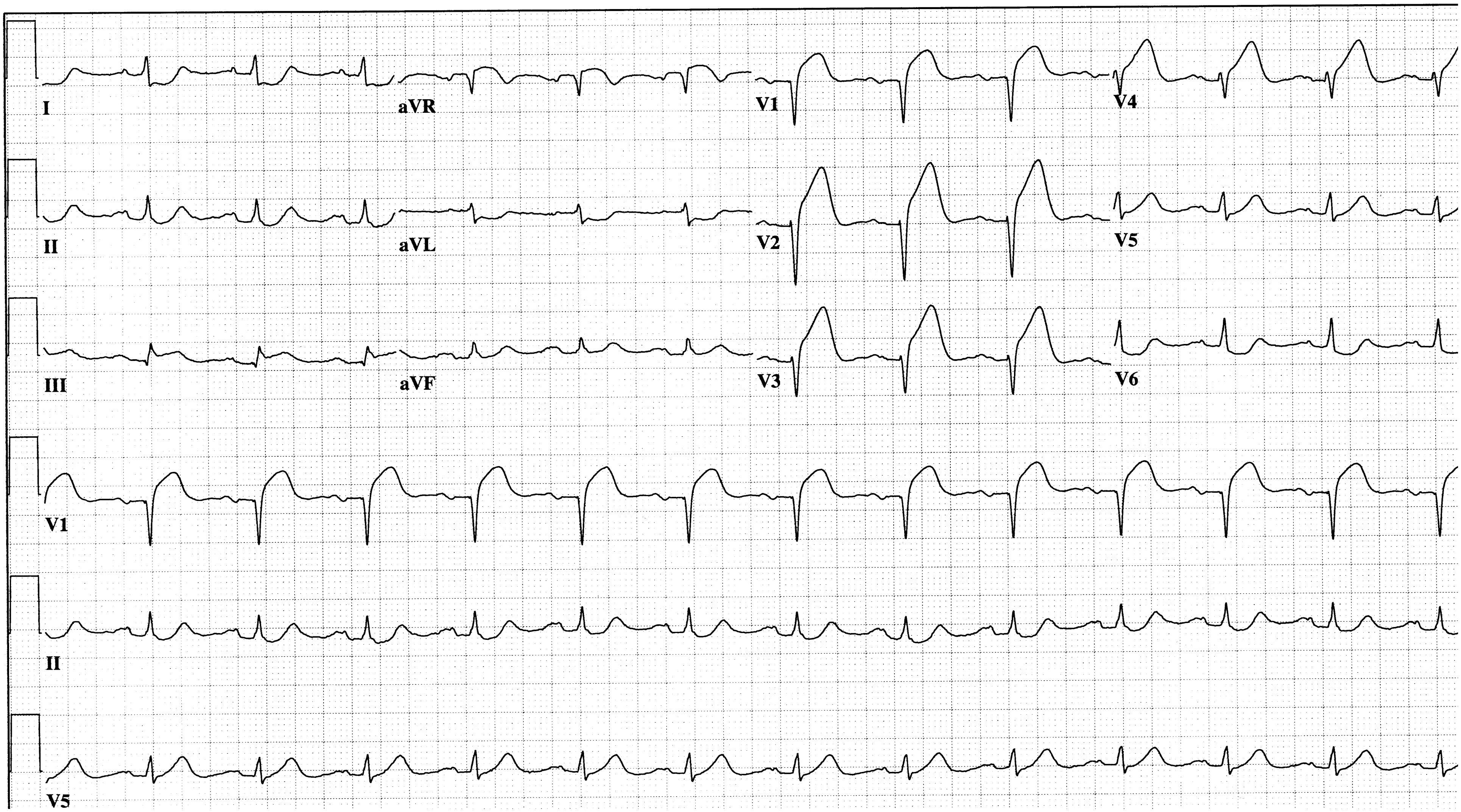
T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______

______



ECG Review 71

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

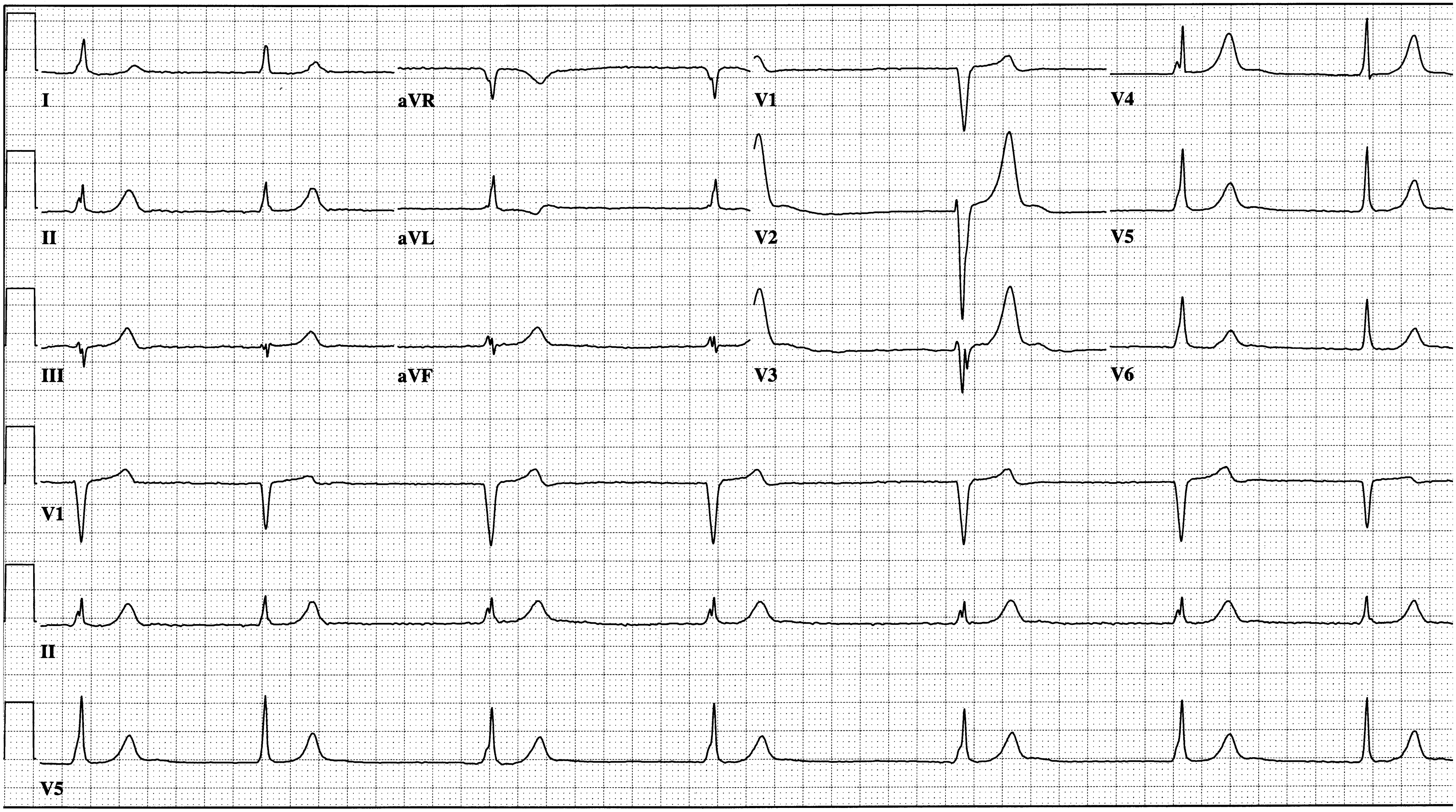
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG Review 72

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

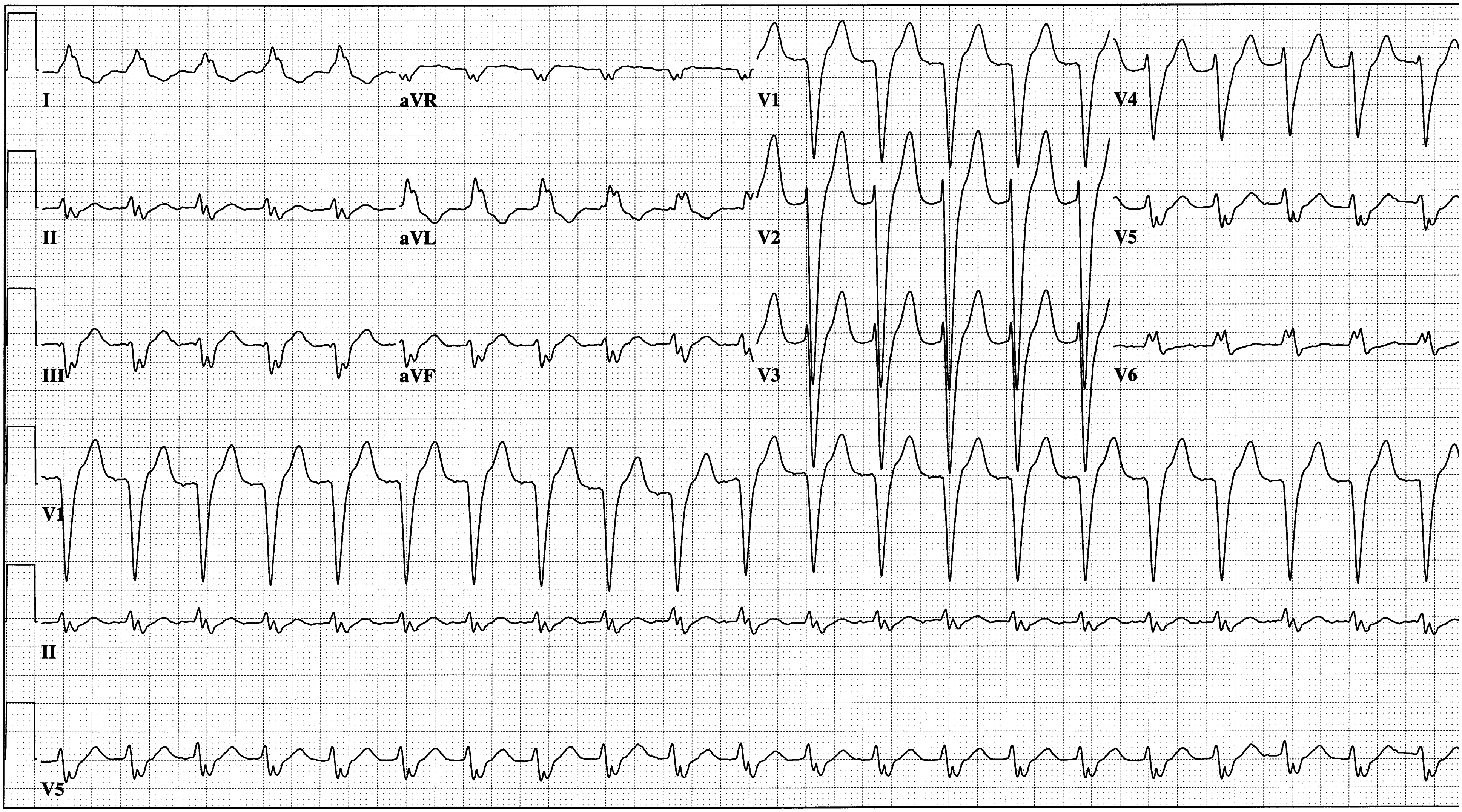
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG Review 73

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

ST segment: ____________________

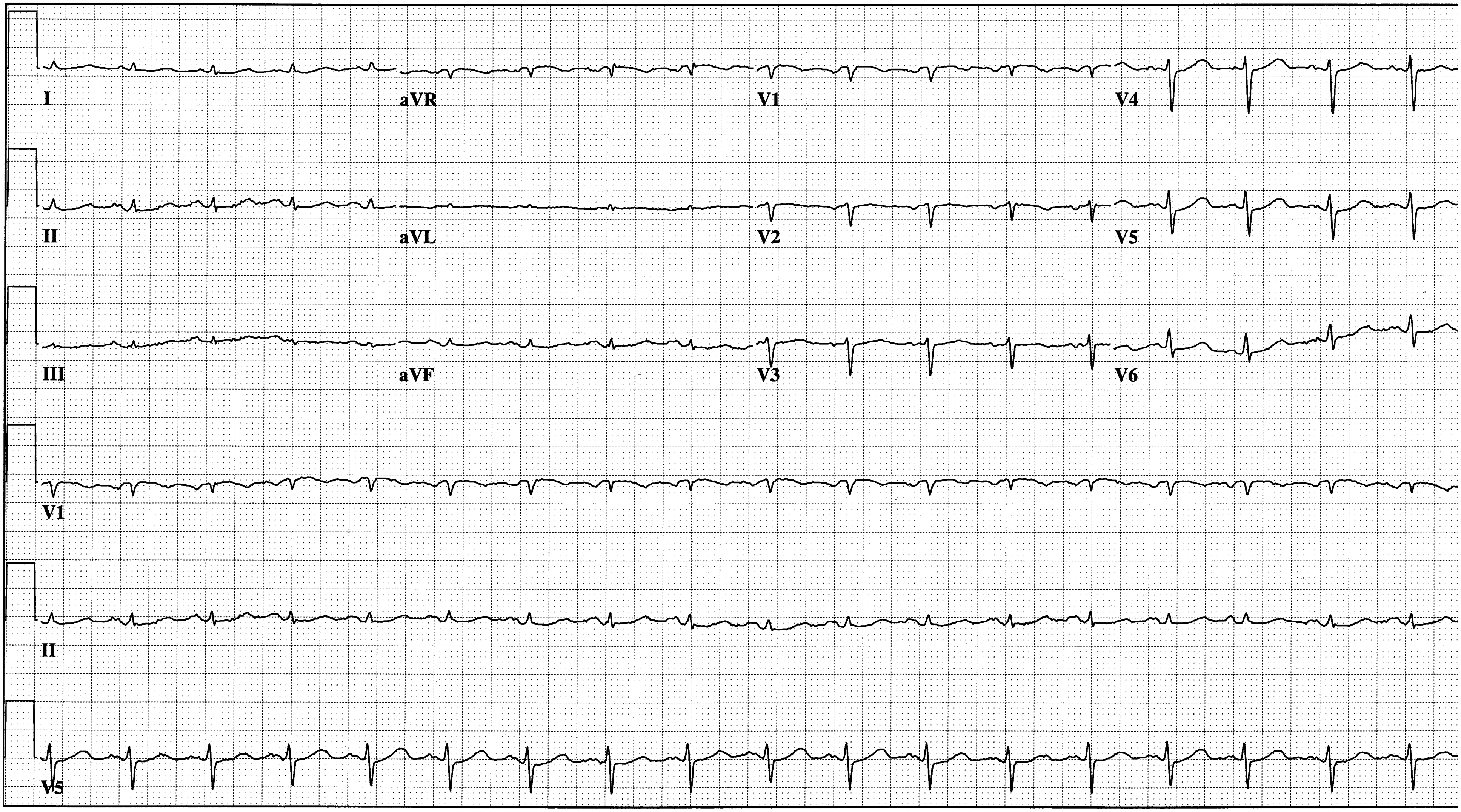
T wave: ____________________

QT interval: ____________________

U wave: ____________________

Diagnosis: ____________________

____



ECG Review 74

Atrial rate: __________

Ventricular rate: __________

Rhythm: __________

P wave: __________

PR interval: __________

QRS complex:

Axis: __________

Duration: __________

Voltage: __________

Morphology: __________

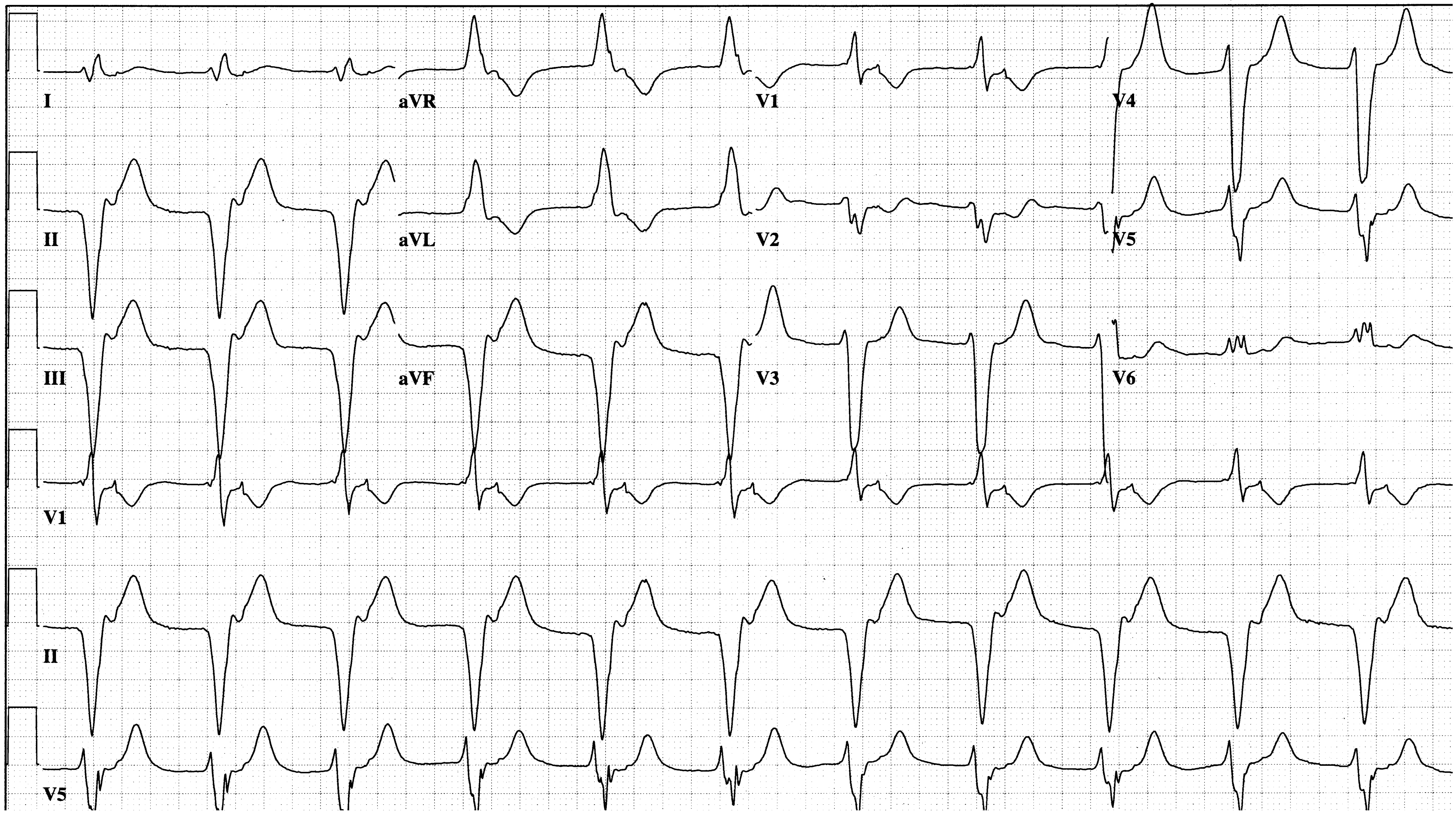
ST segment: __________

T wave: __________

QT interval: __________

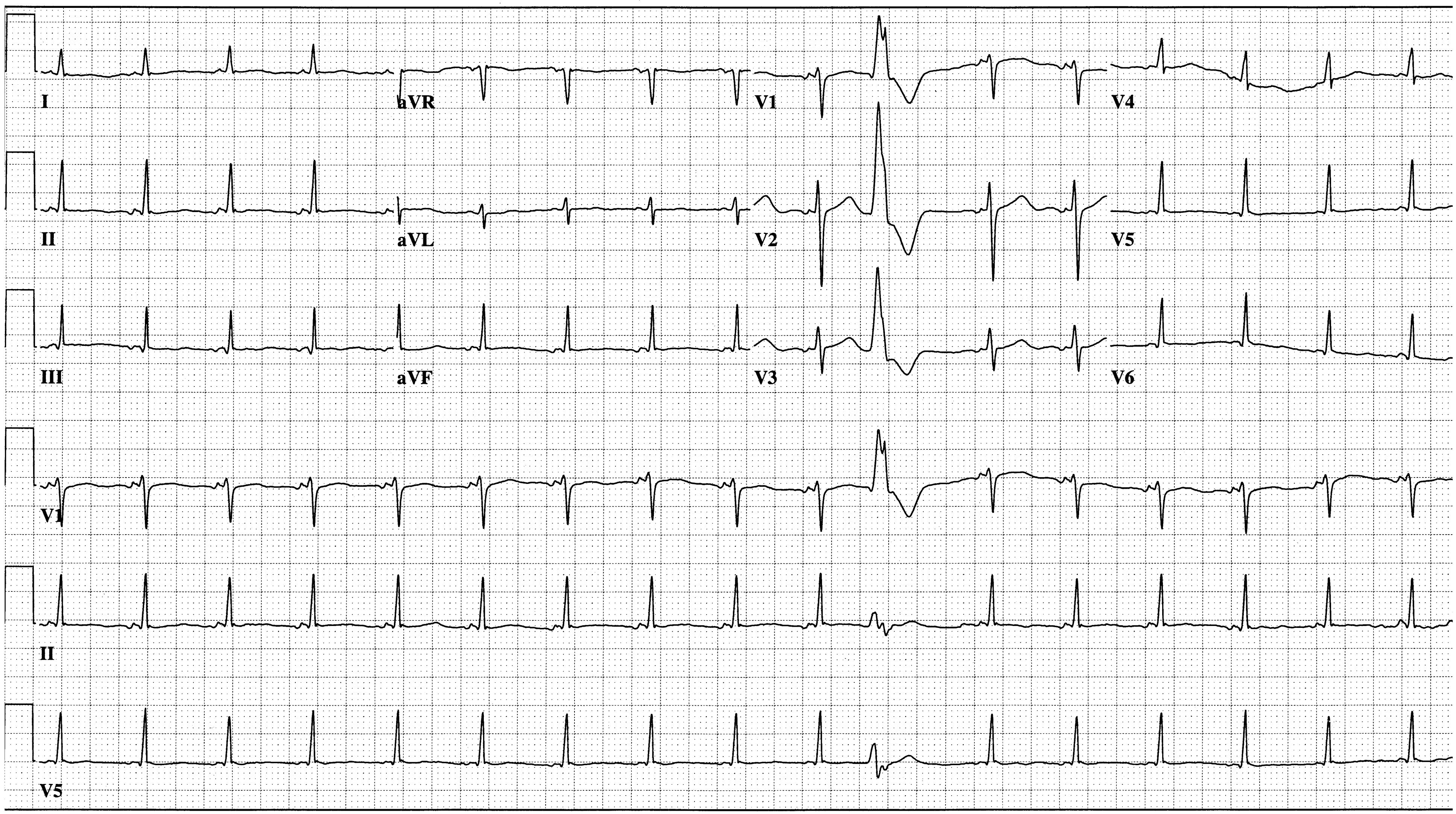
U wave: __________

Diagnosis: __________



ECG Review 75

Atrial rate:	QRS complex:	ST segment:
Ventricular rate:	Axis:	T wave:
Rhythm:	Duration:	QT interval:
P wave:	Voltage:	U wave:
PR interval:	Morphology:	Diagnosis:



ECG Review 76

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

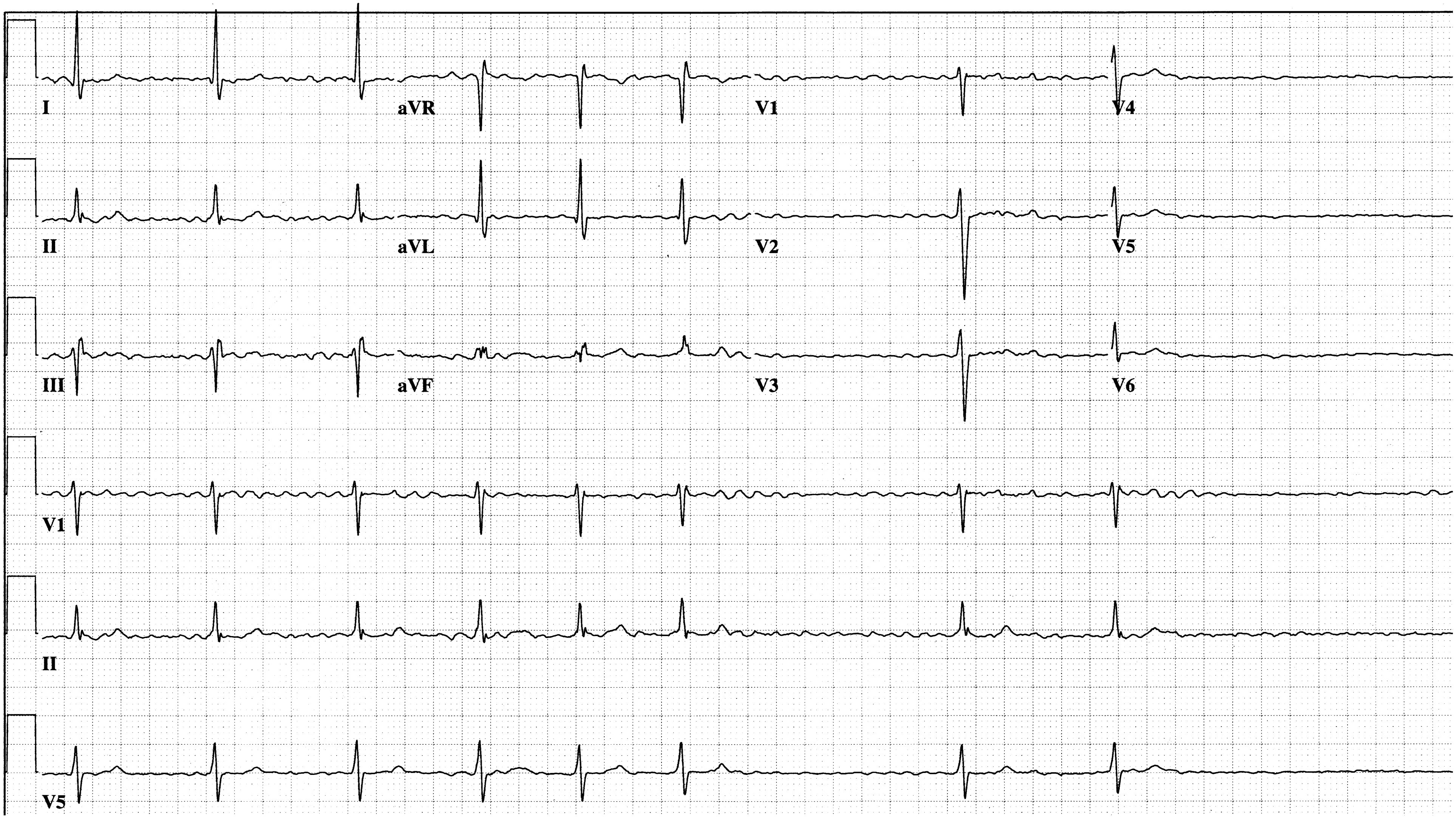
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG Review 77

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

ST segment: ____________________

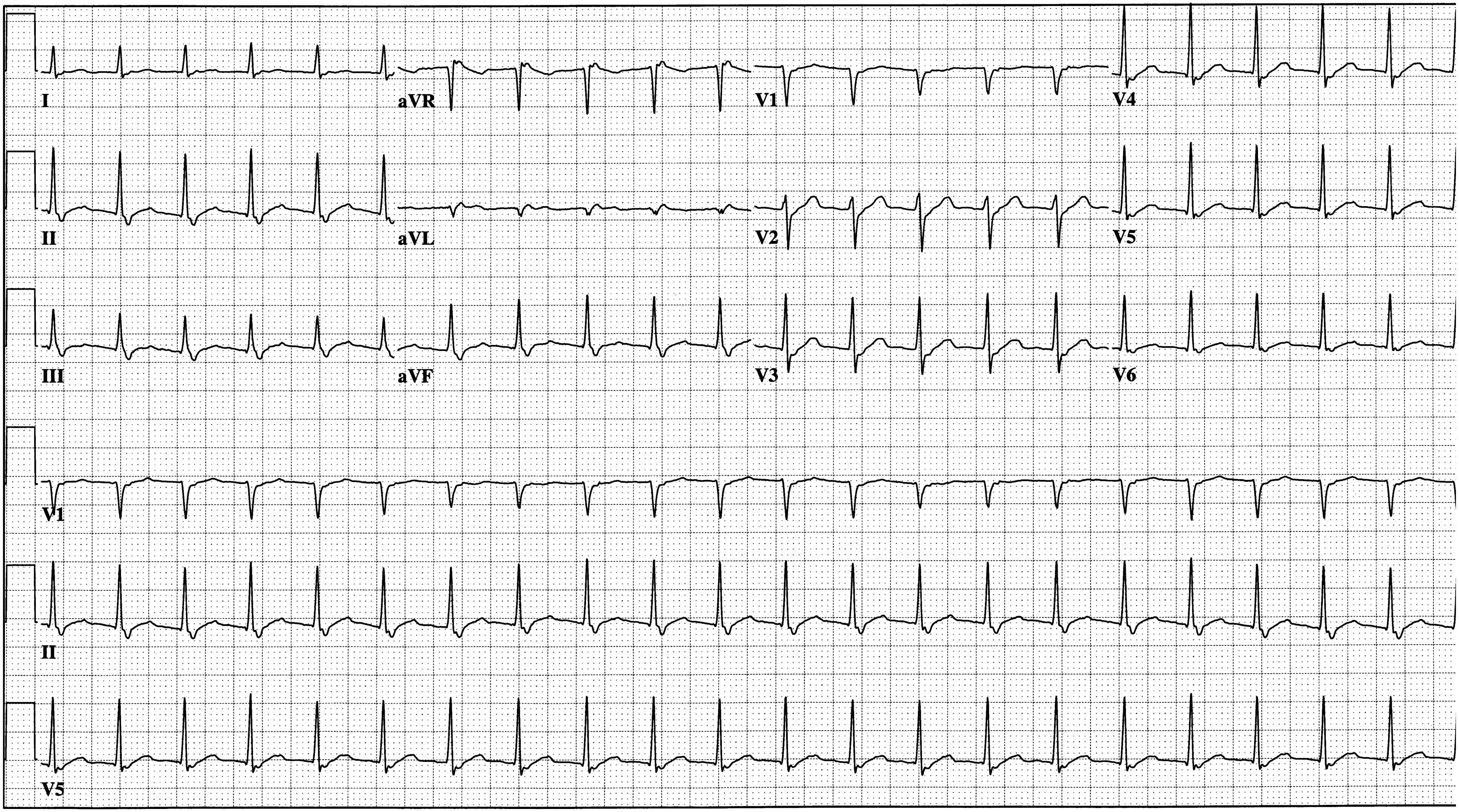
T wave: ____________________

QT interval: ____________________

U wave: ____________________

Diagnosis: ____________________

____



ECG Review 78

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

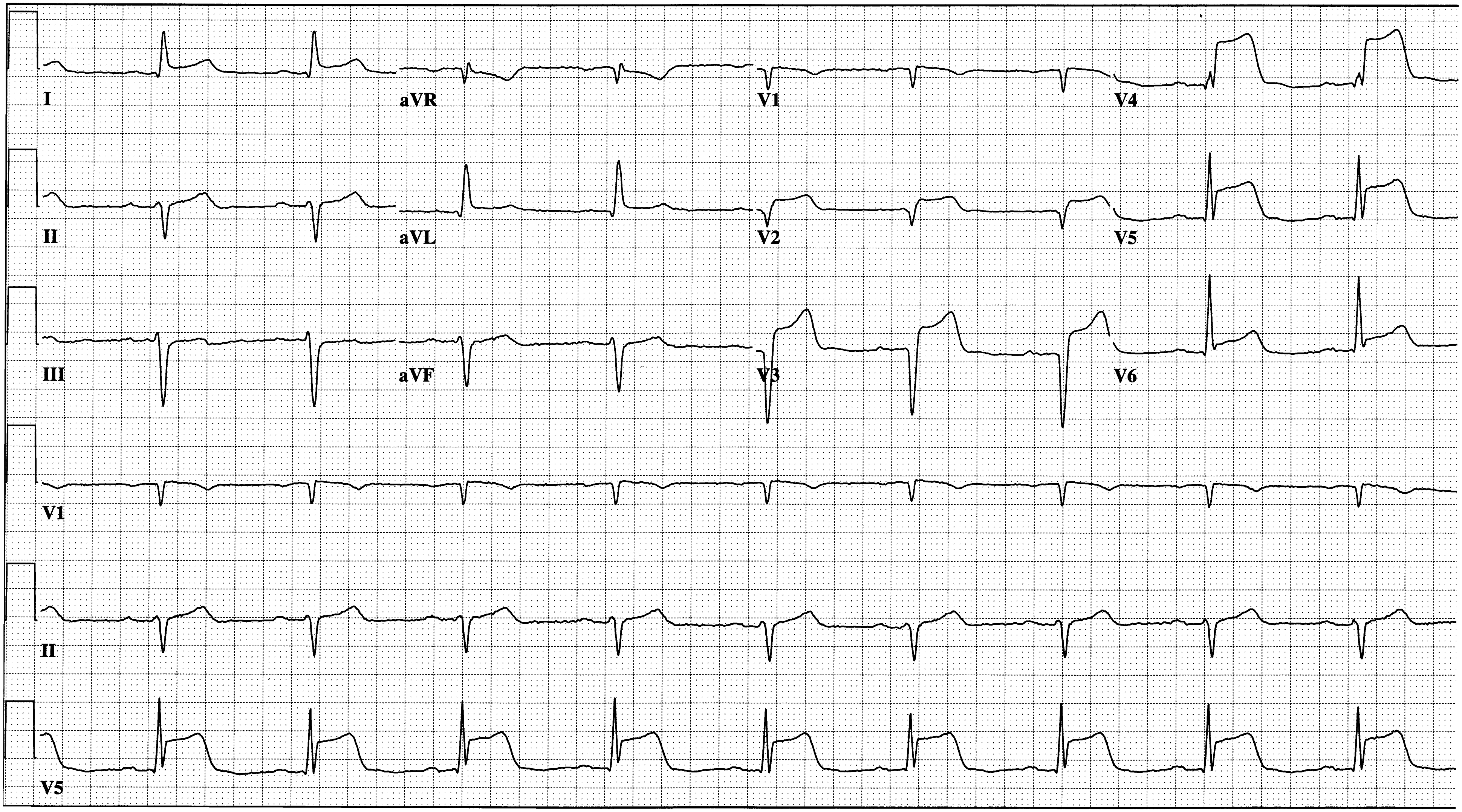
T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________

____



ECG Review 79

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

ST segment: ______________________

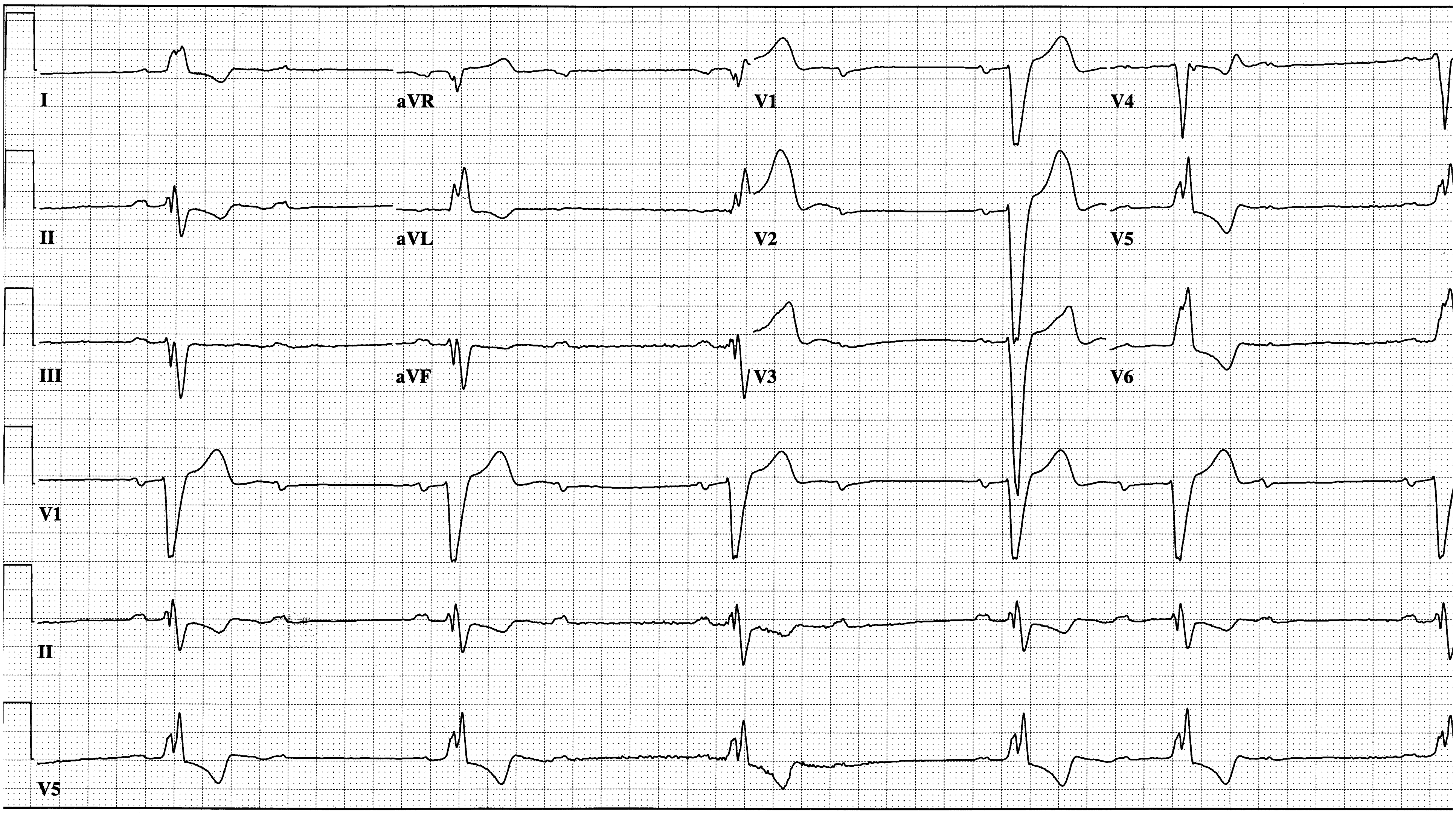
T wave: ______________________

QT interval: ______________________

U wave: ______________________

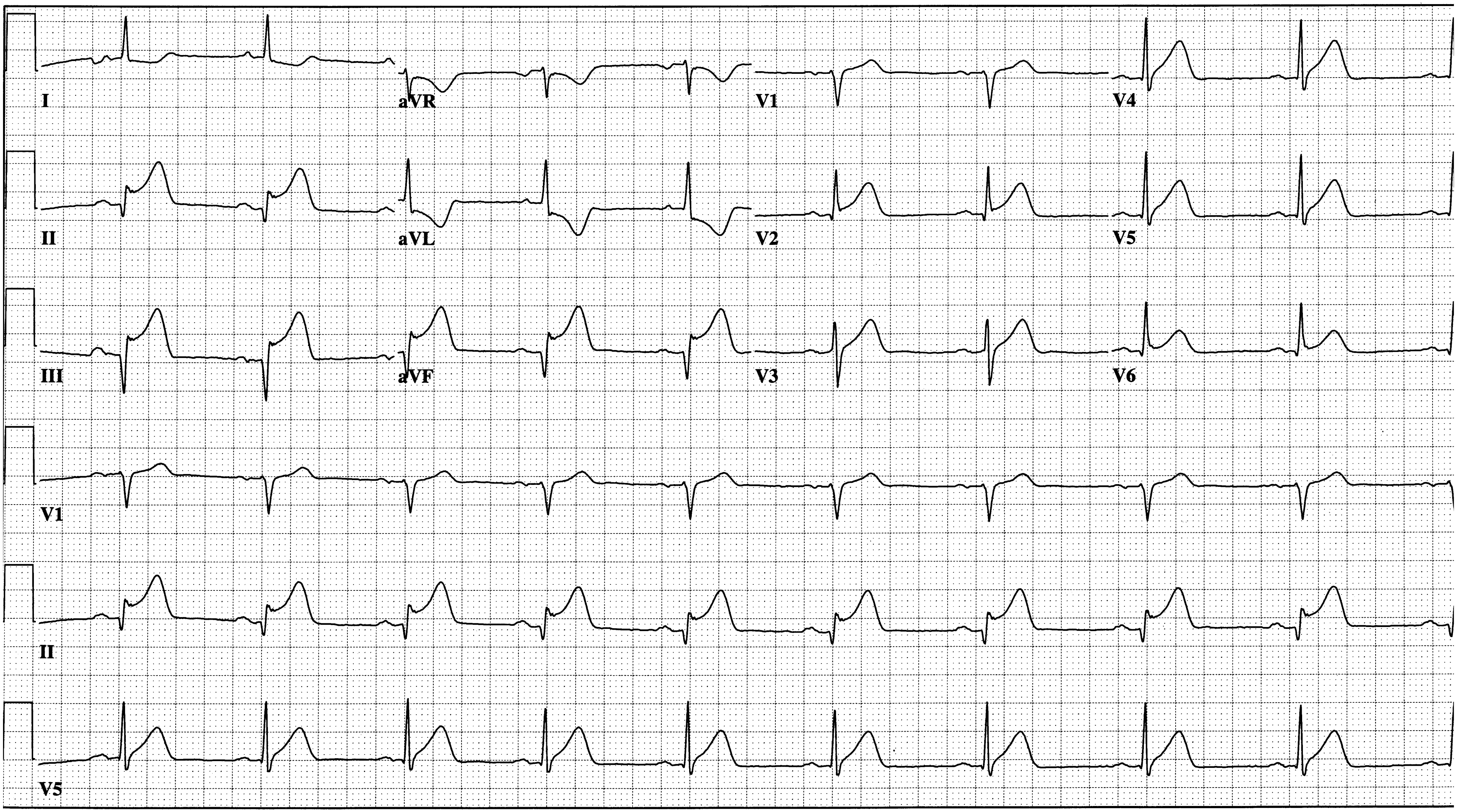
Diagnosis: ______________________

____



ECG Review 80

Atrial rate:	QRS complex:	ST segment:
Ventricular rate:	Axis:	T wave:
Rhythm:	Duration:	QT interval:
P wave:	Voltage:	U wave:
PR interval:	Morphology:	Diagnosis:



ECG Review 81

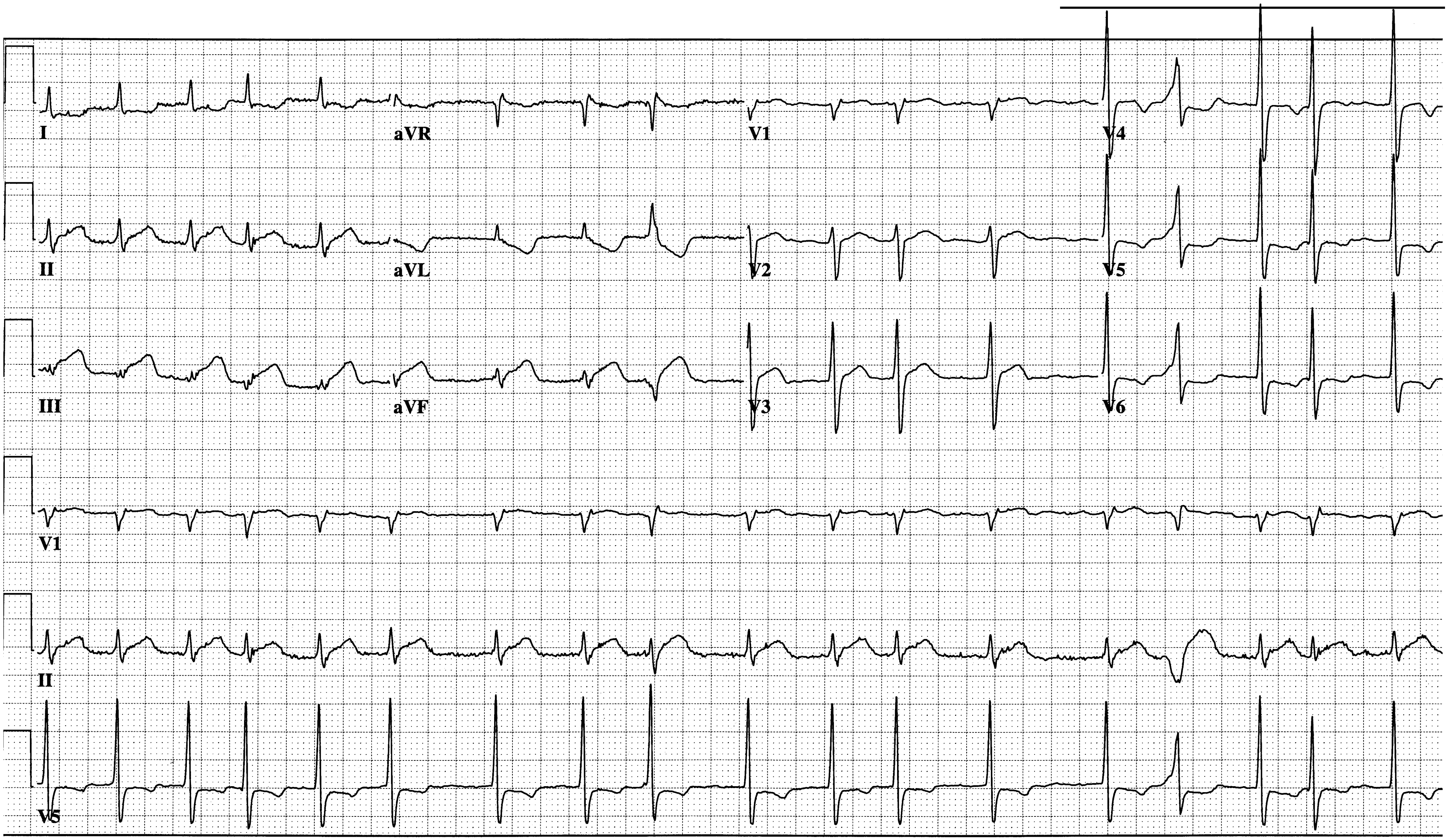
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

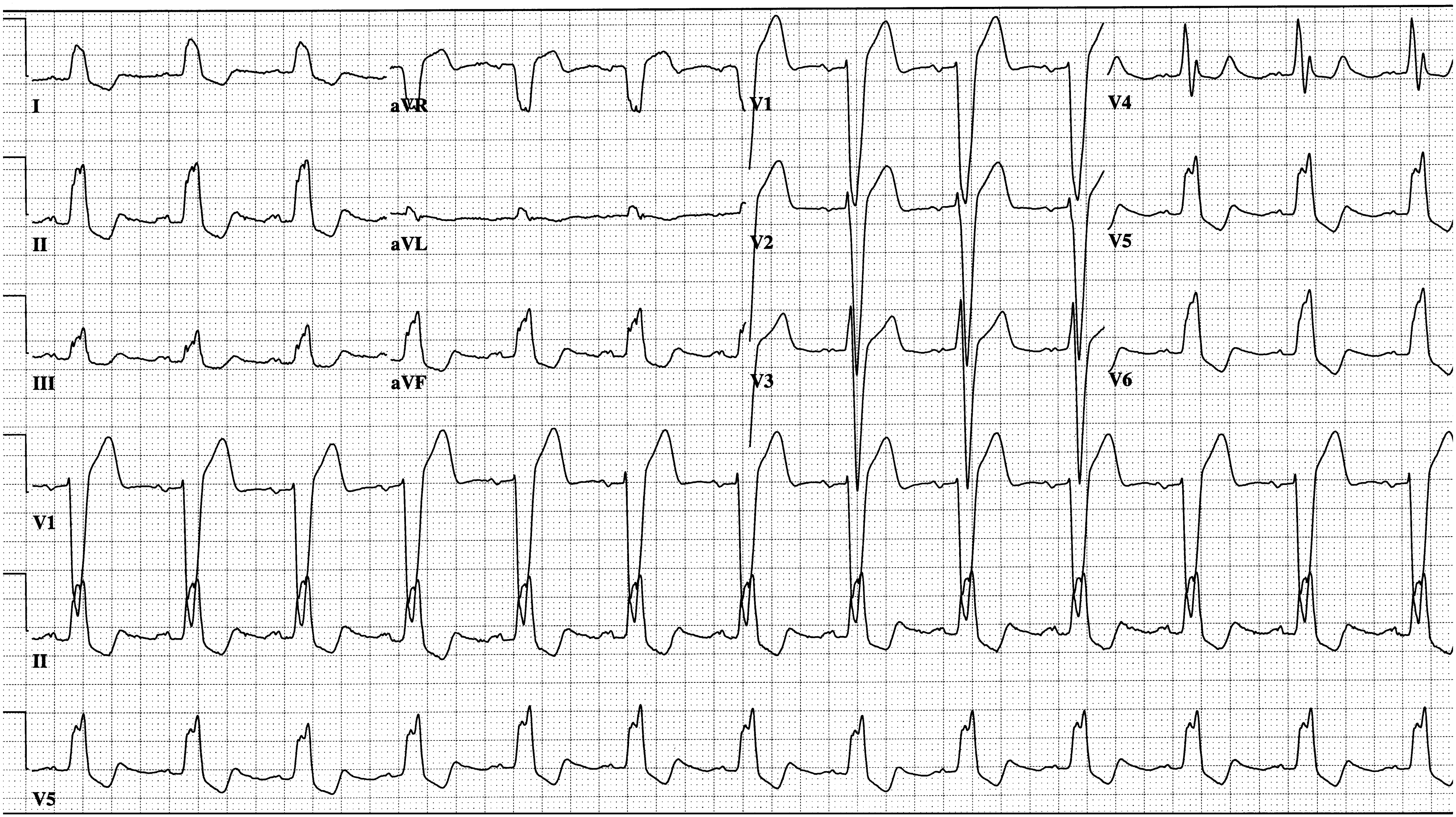
P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG Review 82

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG Review 83

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

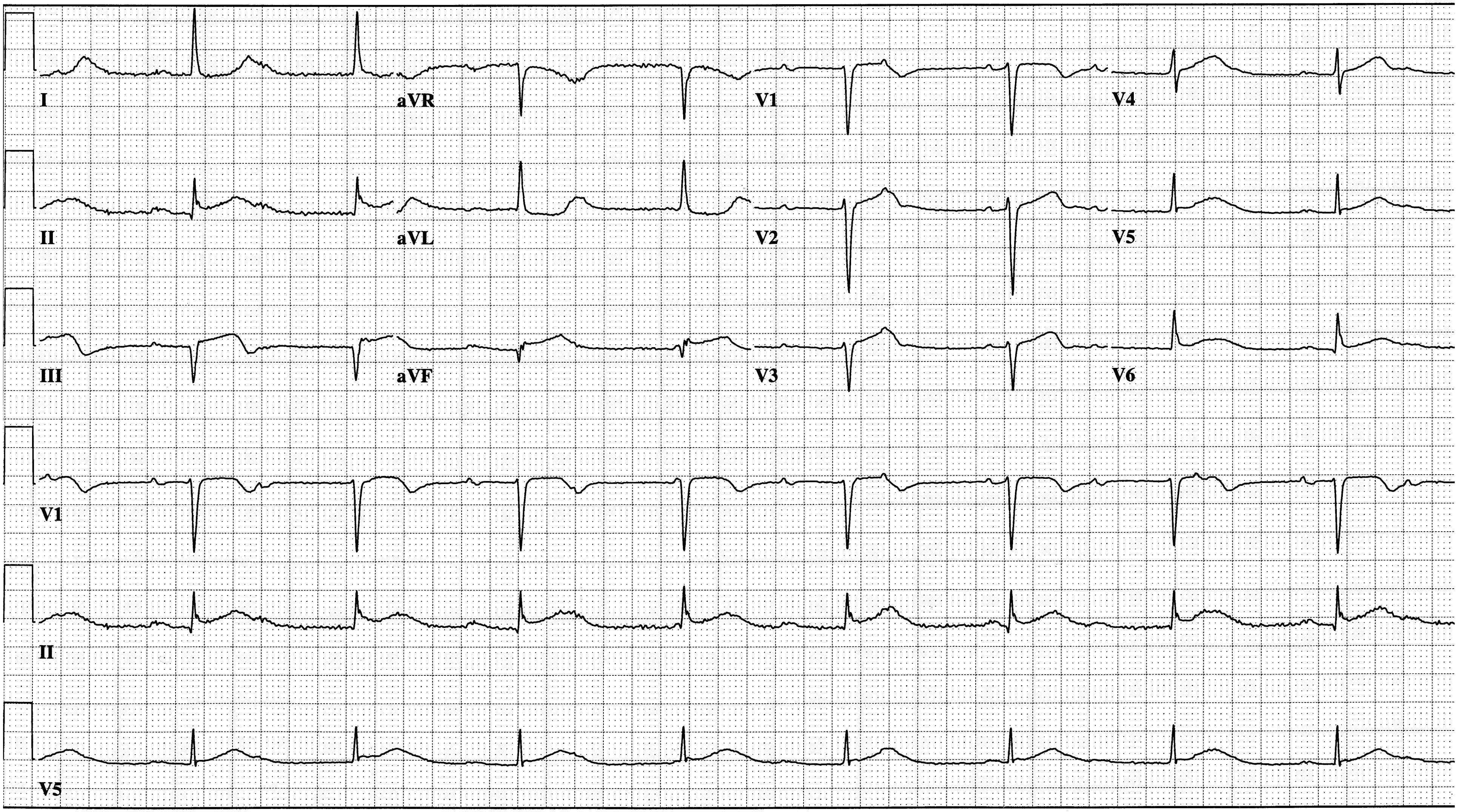
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______

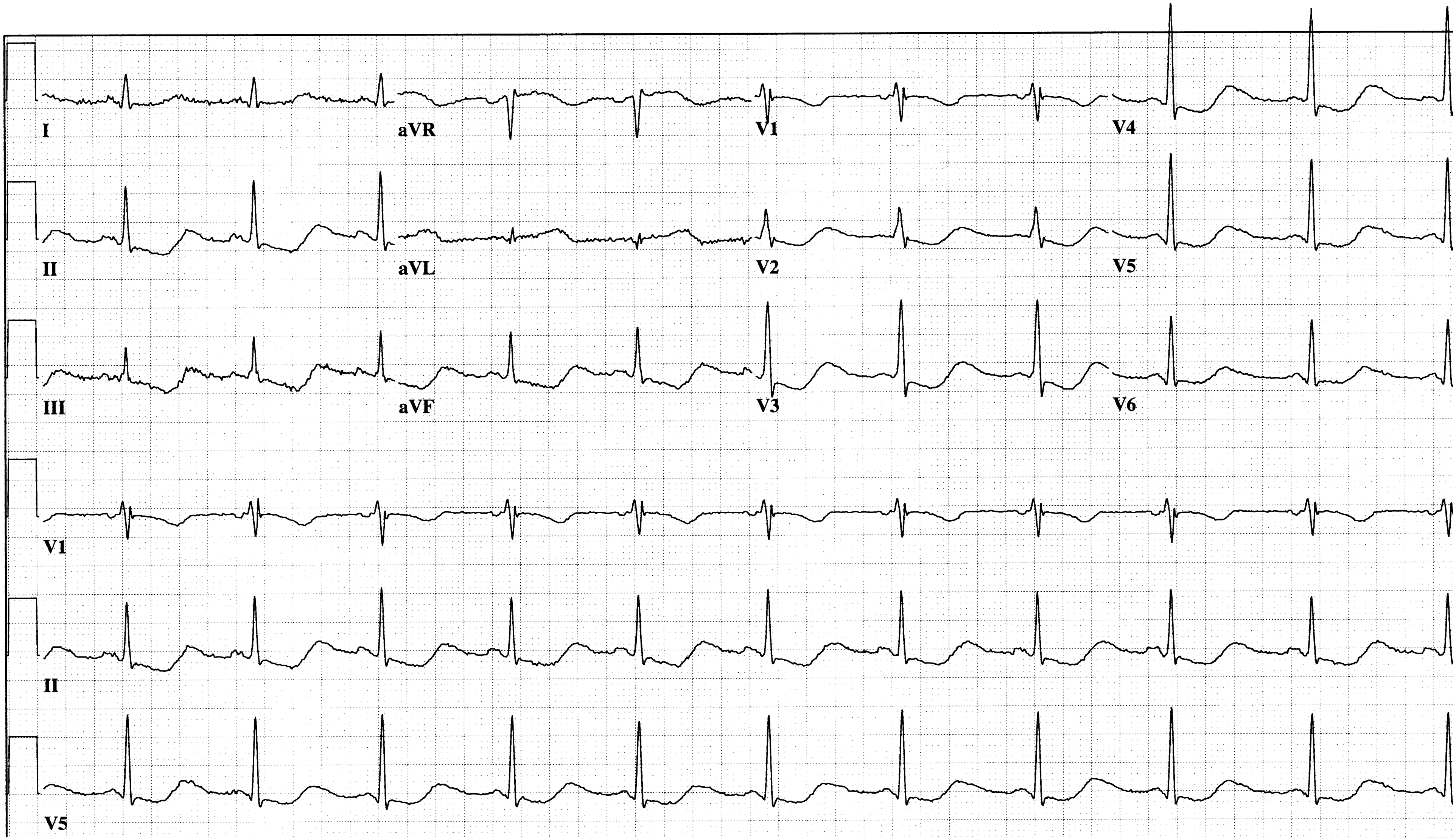


ECG Review 84

Atrial rate: __________
Ventricular rate: __________
Rhythm: __________
P wave: __________
PR interval: __________

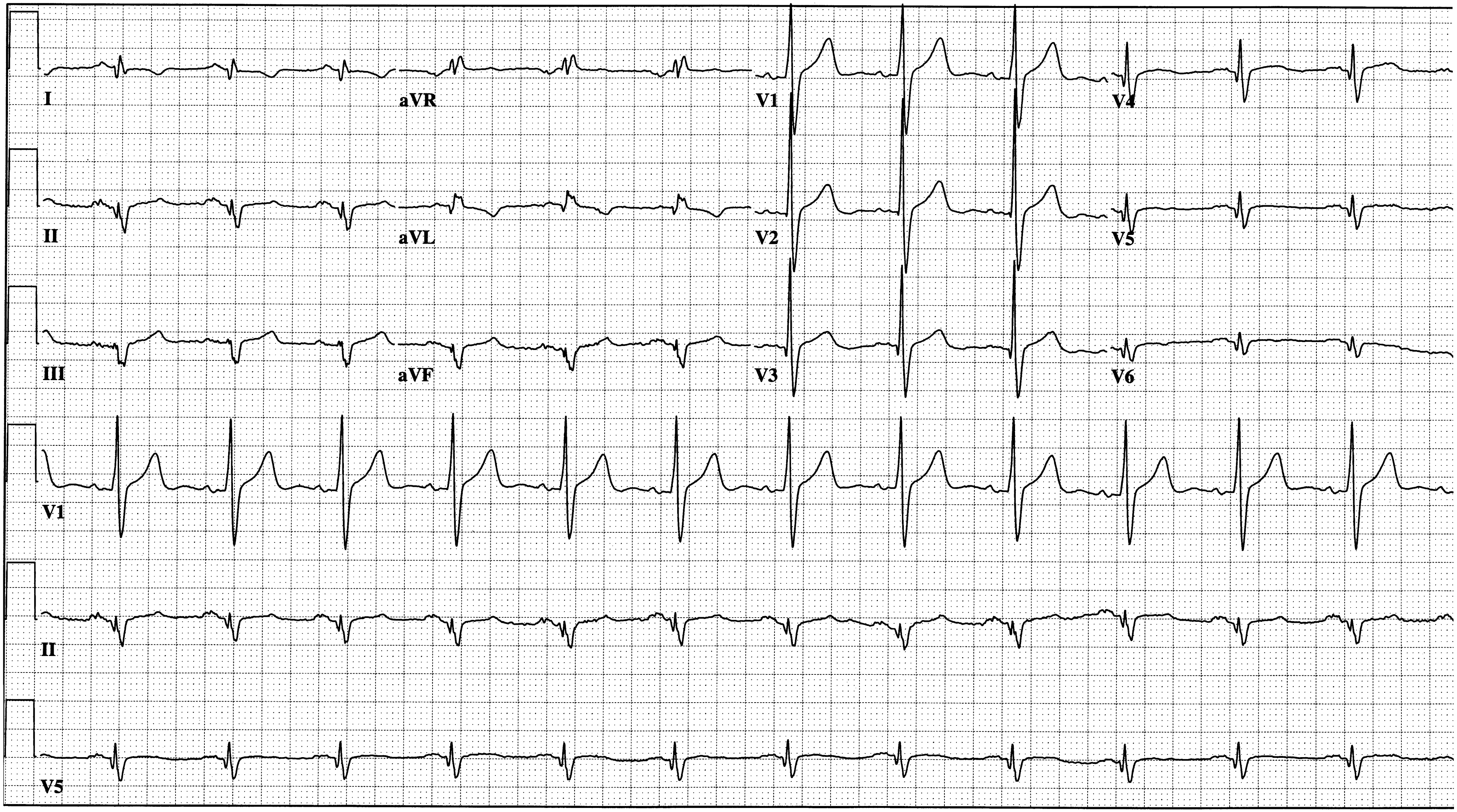
QRS complex:
Axis: __________
Duration: __________
Voltage: __________
Morphology: __________

ST segment: __________
T wave: __________
QT interval: __________
U wave: __________
Diagnosis: __________



ECG Review 85

Atrial rate: ______	QRS complex:	ST segment: ______
Ventricular rate: ______	Axis: ______	T wave: ______
Rhythm: ______	Duration: ______	QT interval: ______
P wave: ______	Voltage: ______	U wave: ______
PR interval: ______	Morphology: ______	Diagnosis: ______



ECG Review 86

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

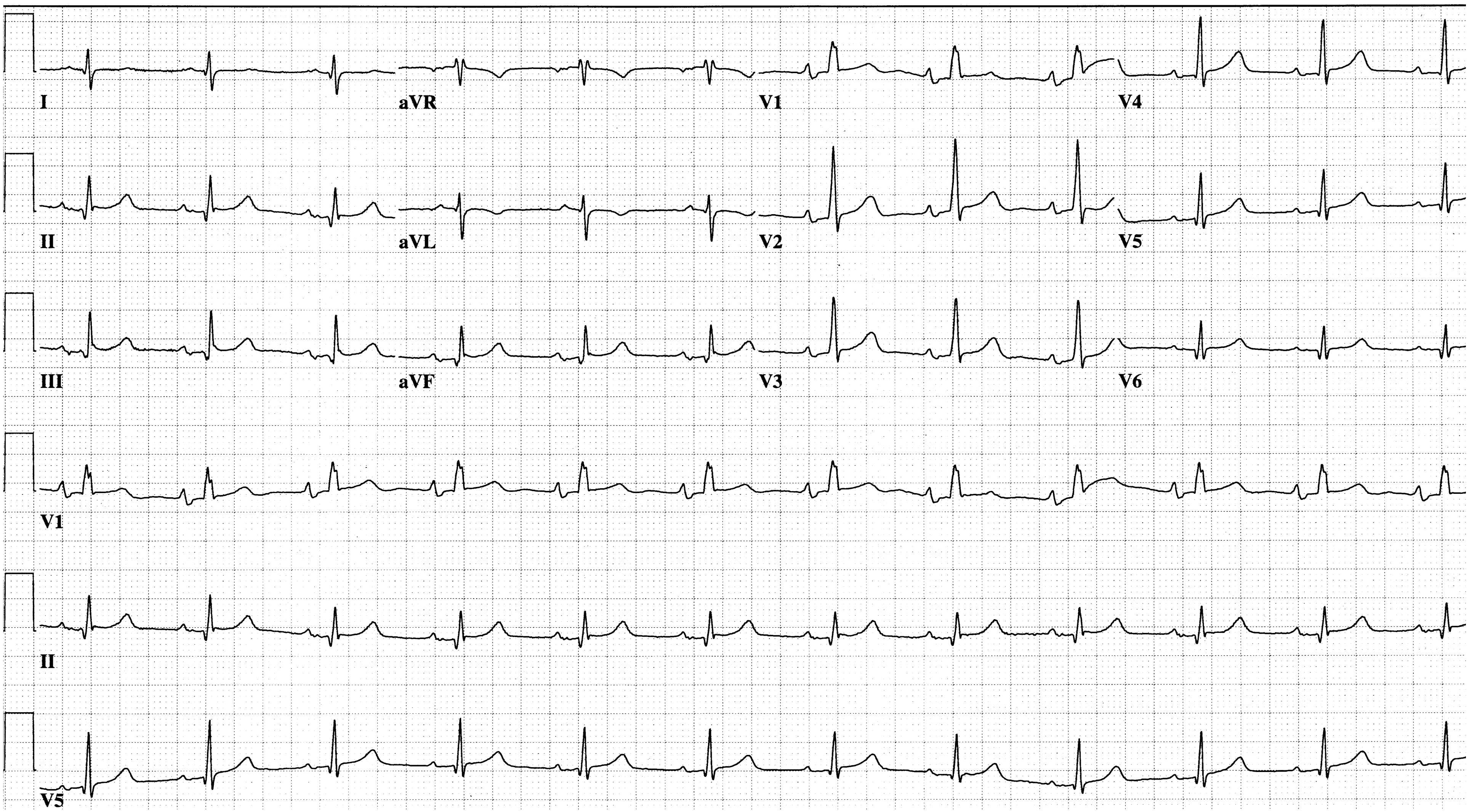
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______

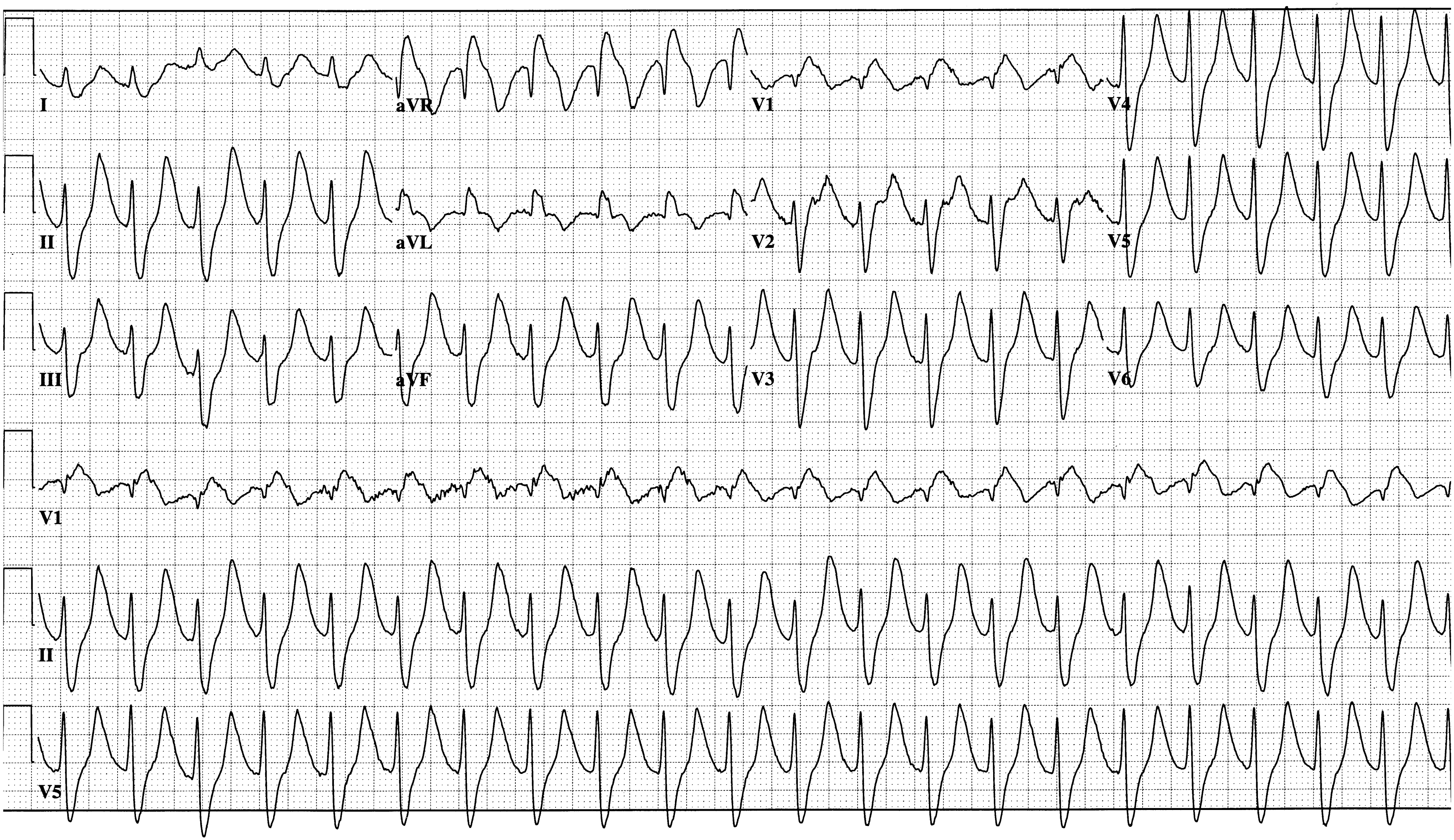


ECG Review 87

Atrial rate: ______
Ventricular rate: ______
Rhythm: ______
P wave: ______
PR interval: ______

QRS complex:
Axis: ______
Duration: ______
Voltage: ______
Morphology: ______

ST segment: ______
T wave: ______
QT interval: ______
U wave: ______
Diagnosis: ______



ECG Review 88

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

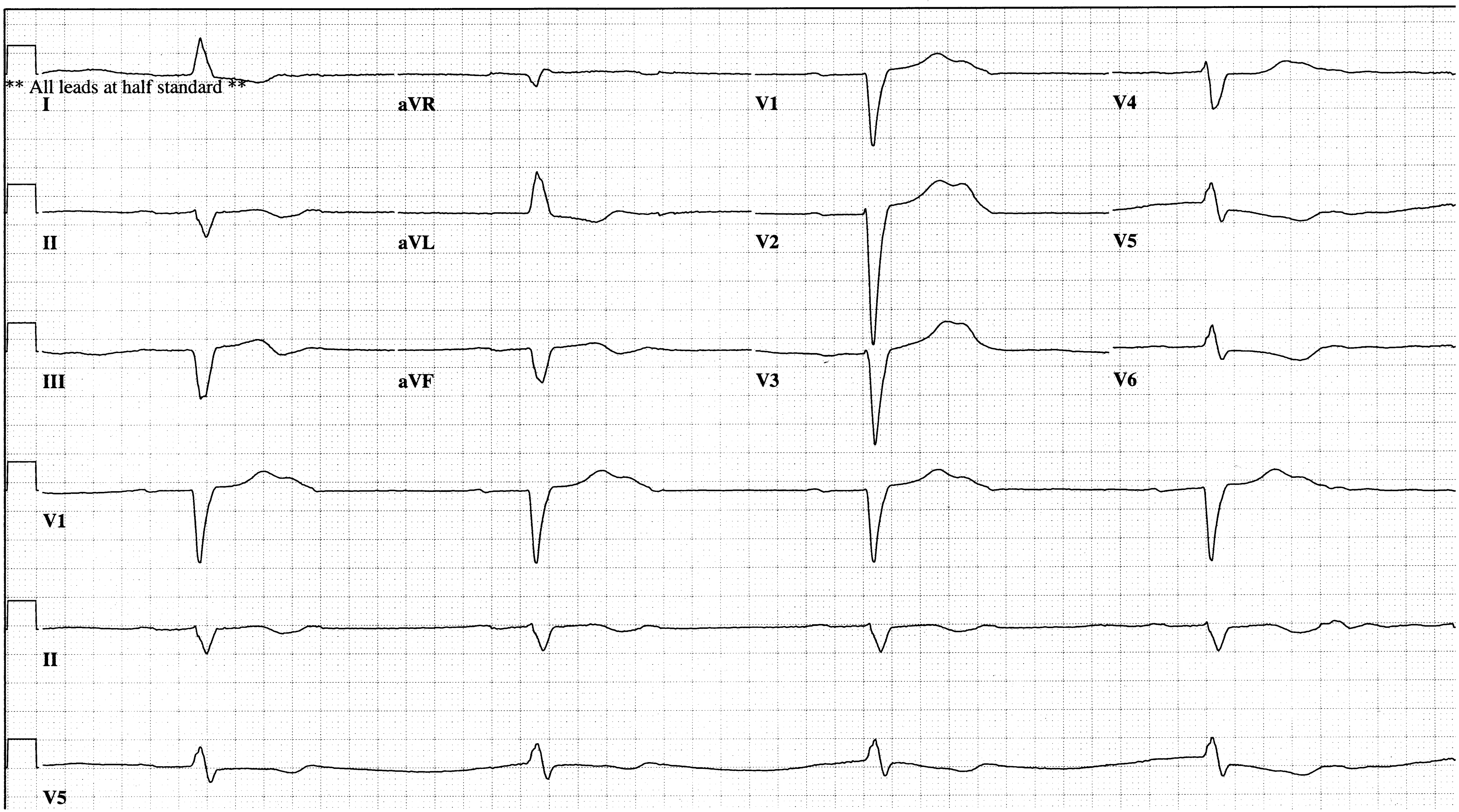
ST segment: ______

T wave: ______

QT interval: ______

U wave: ______

Diagnosis: ______



ECG Review 89

Atrial rate: ______________________

Ventricular rate: ______________________

Rhythm: ______________________

P wave: ______________________

PR interval: ______________________

QRS complex:

Axis: ______________________

Duration: ______________________

Voltage: ______________________

Morphology: ______________________

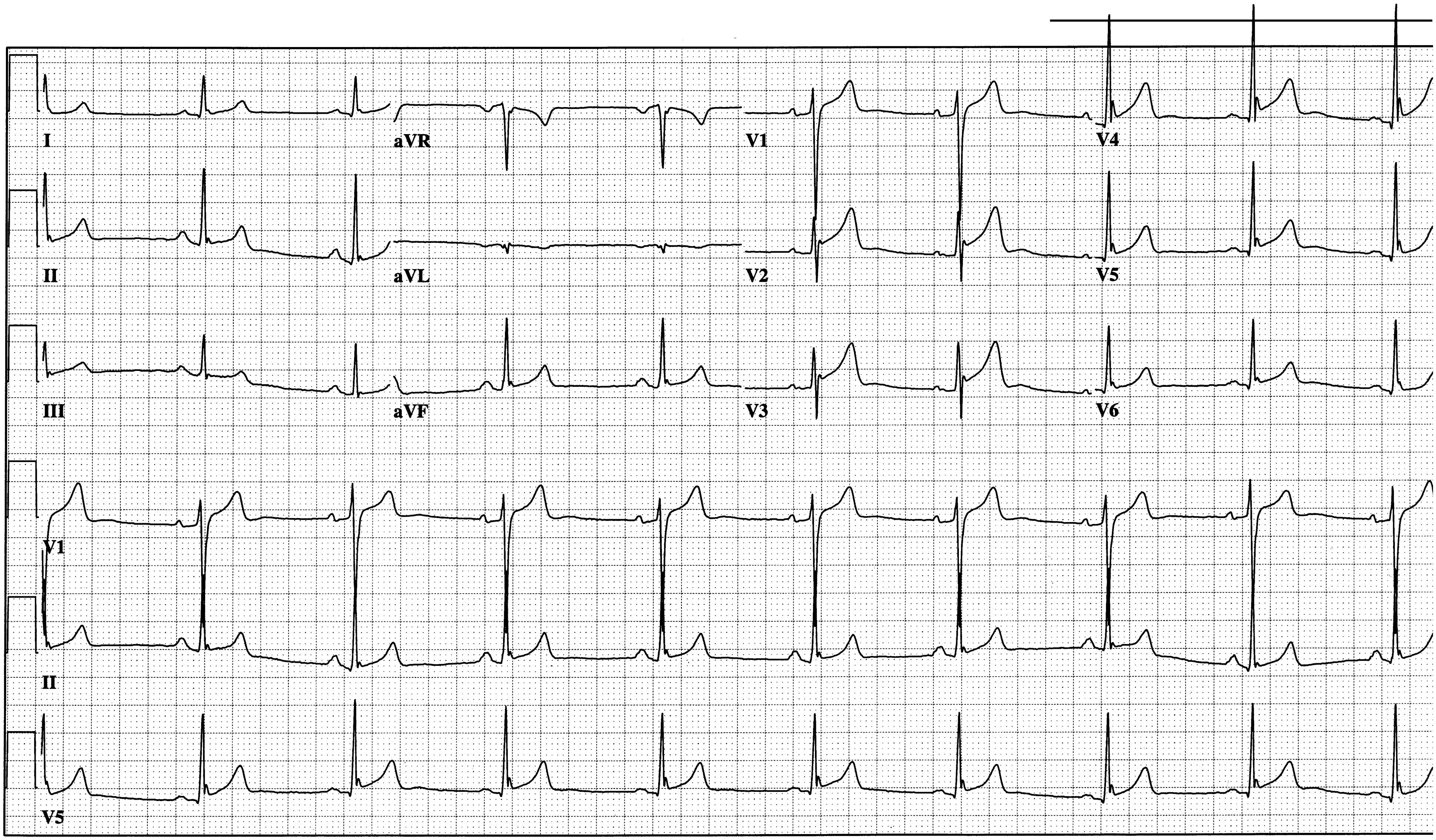
ST segment: ______________________

T wave: ______________________

QT interval: ______________________

U wave: ______________________

Diagnosis: ______________________



ECG Review 90

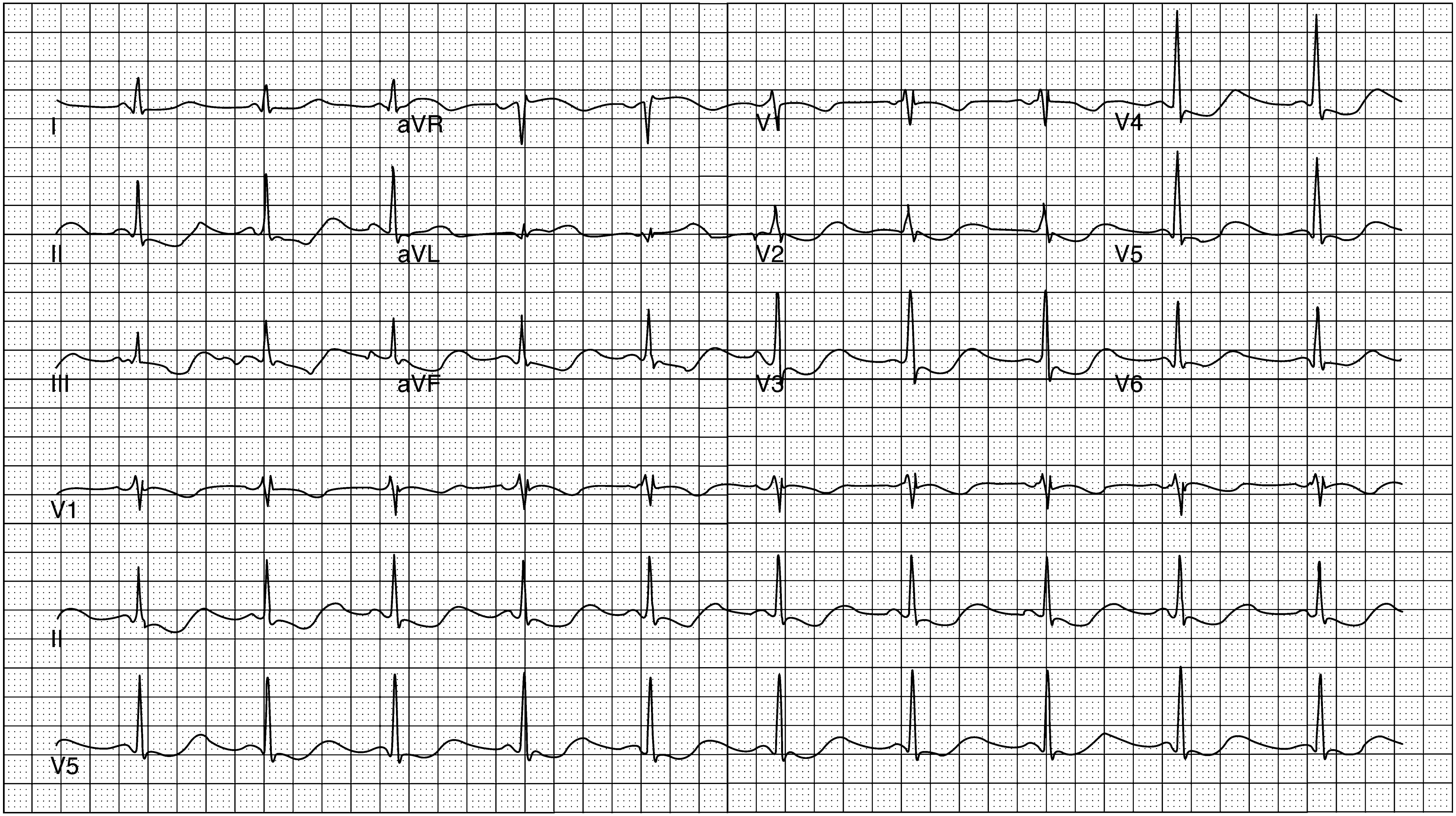
Atrial rate: ______ QRS complex: ST segment: ______

Ventricular rate: ______ Axis: ______ T wave: ______

Rhythm: ______ Duration: ______ QT interval: ______

P wave: ______ Voltage: ______ U wave: ______

PR interval: ______ Morphology: ______ Diagnosis: ______



ECG Review 91

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

ST segment: ____________________

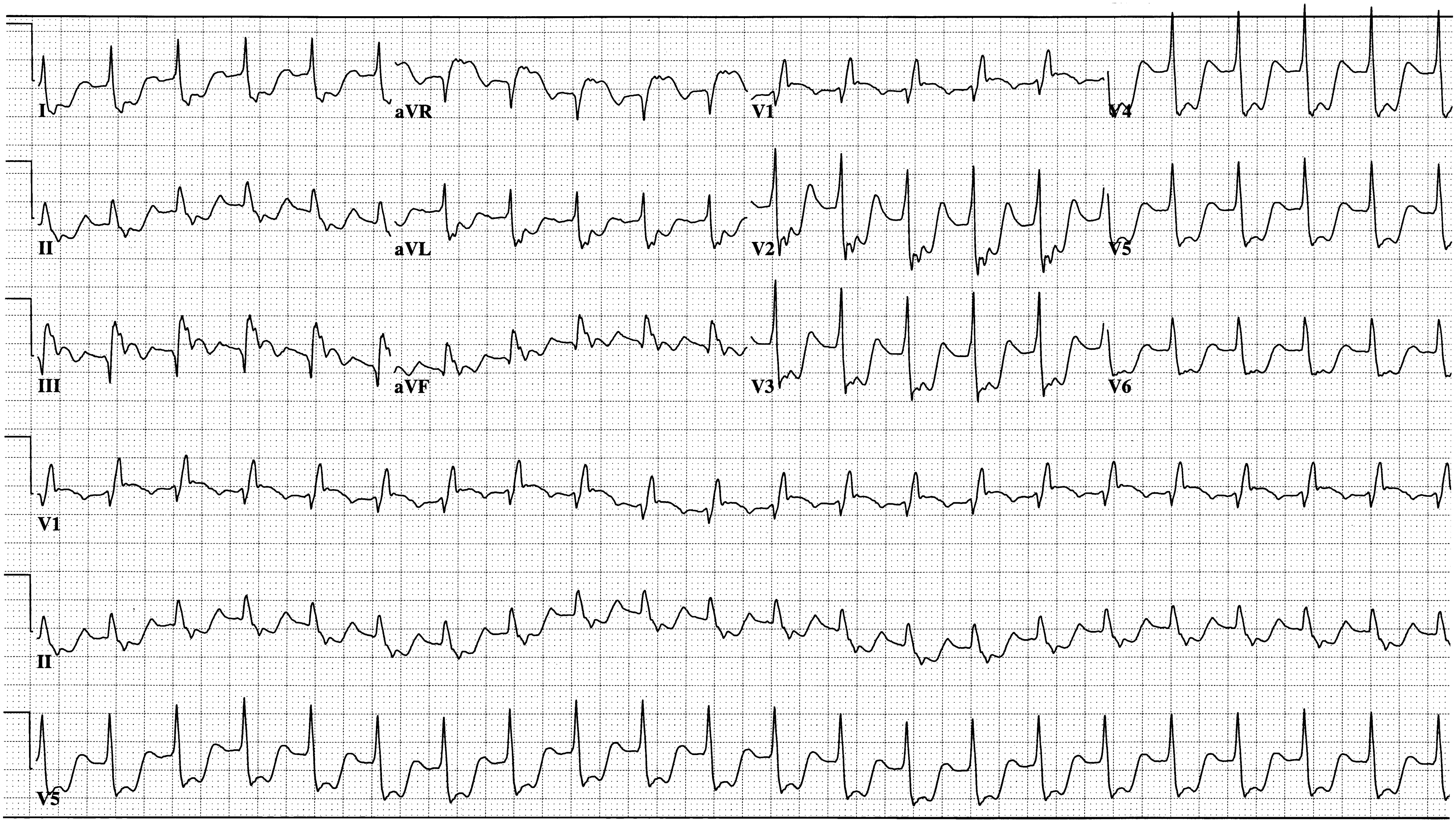
T wave: ____________________

QT interval: ____________________

U wave: ____________________

Diagnosis: ____________________

____



ECG Review 92

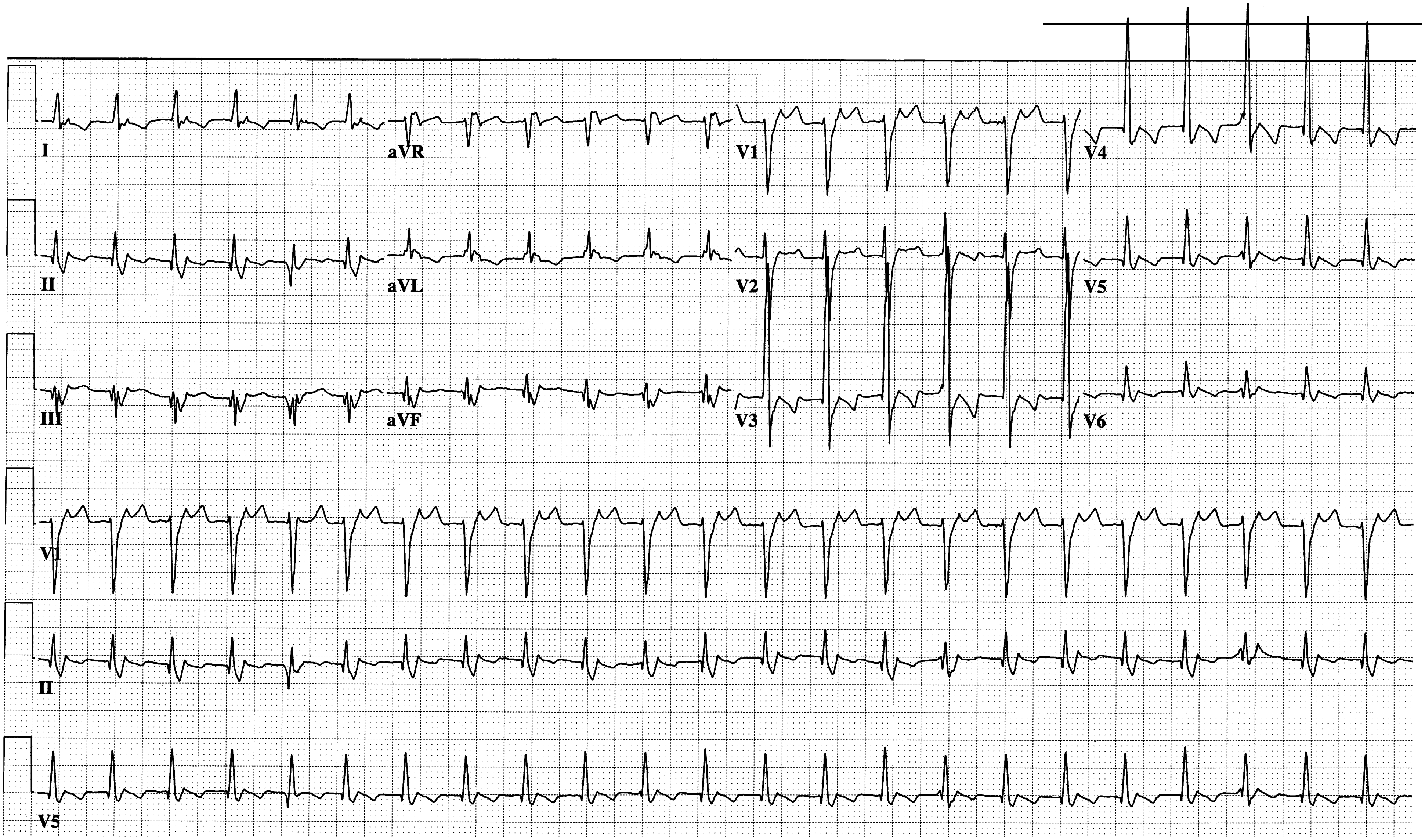
Atrial rate: ______________________ QRS complex: ST segment: ______________________

Ventricular rate: ______________________ Axis: ______________________ T wave: ______________________

Rhythm: ______________________ Duration: ______________________ QT interval: ______________________

P wave: ______________________ Voltage: ______________________ U wave: ______________________

PR interval: ______________________ Morphology: ______________________ Diagnosis: ______________________

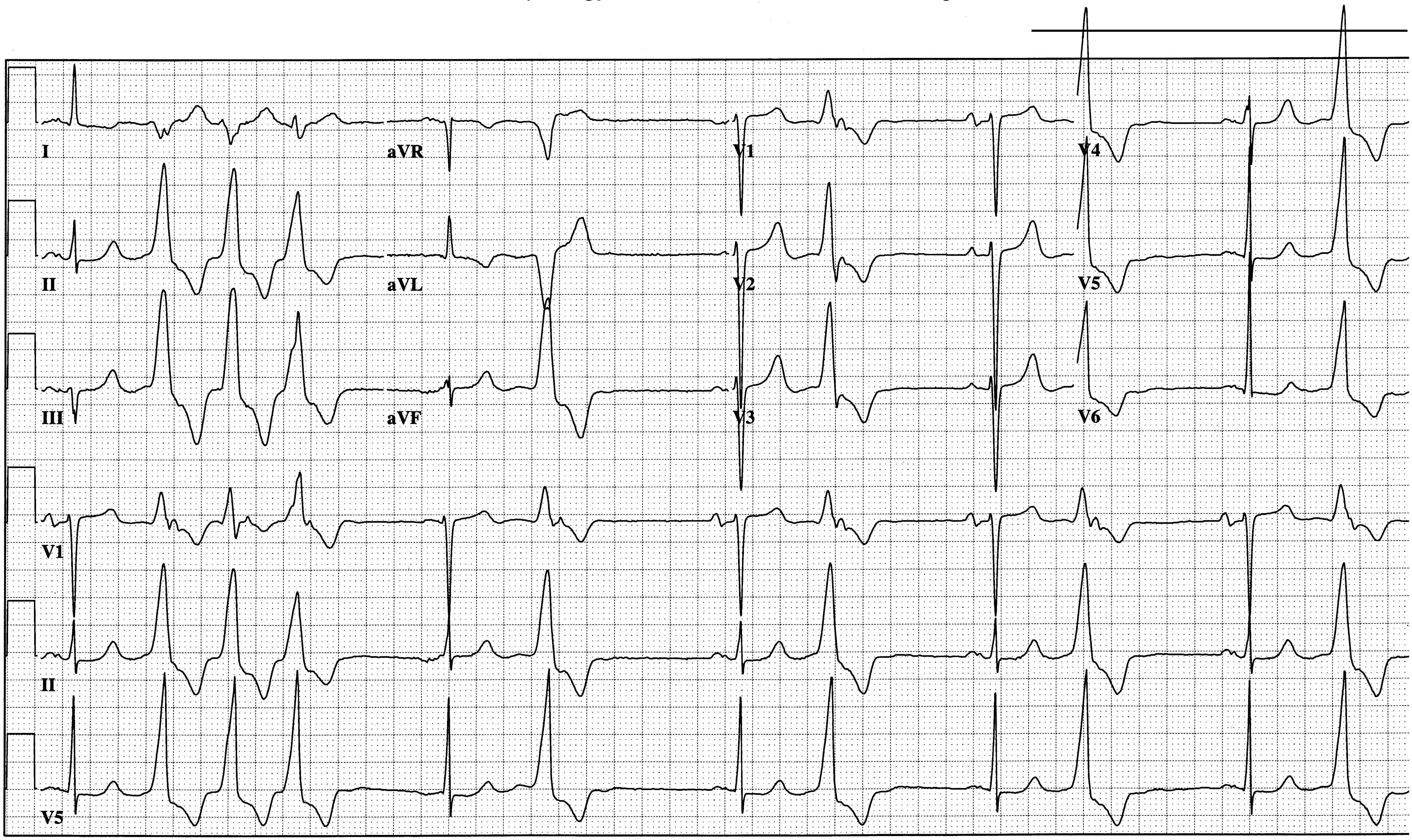


ECG Review 93

Atrial rate: __________
Ventricular rate: __________
Rhythm: __________
P wave: __________
PR interval: __________

QRS complex:
Axis: __________
Duration: __________
Voltage: __________
Morphology: __________

ST segment: __________
T wave: __________
QT interval: __________
U wave: __________
Diagnosis: __________

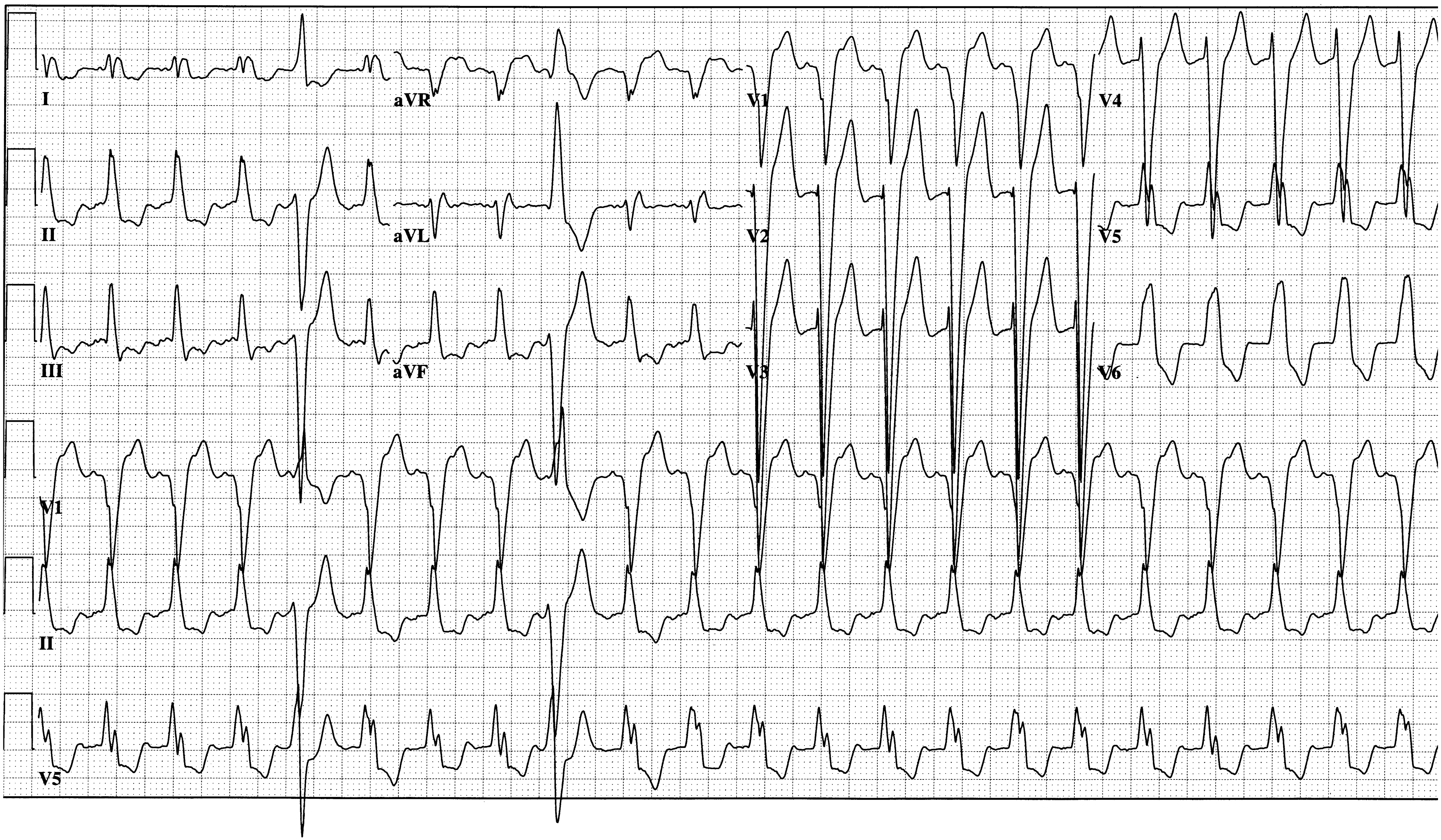


ECG Review 94

Atrial rate: ______
Ventricular rate: ______
Rhythm: ______
P wave: ______
PR interval: ______

QRS complex:
Axis: ______
Duration: ______
Voltage: ______
Morphology: ______

ST segment: ______
T wave: ______
QT interval: ______
U wave: ______
Diagnosis: ______



ECG Review 95

Atrial rate: ______

Ventricular rate: ______

Rhythm: ______

P wave: ______

PR interval: ______

QRS complex:

Axis: ______

Duration: ______

Voltage: ______

Morphology: ______

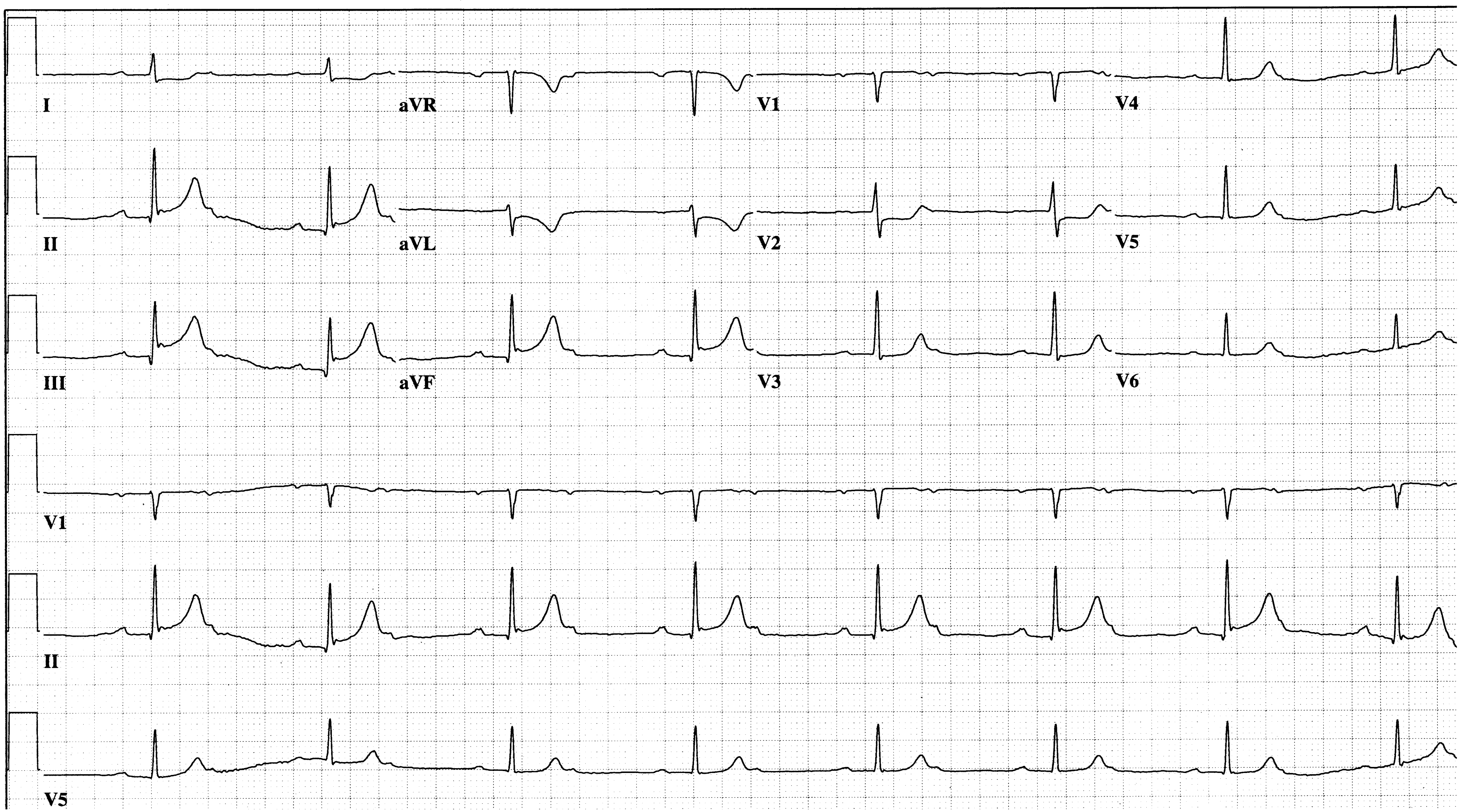
ST segment: ______

T wave: ______

QT interval: ______

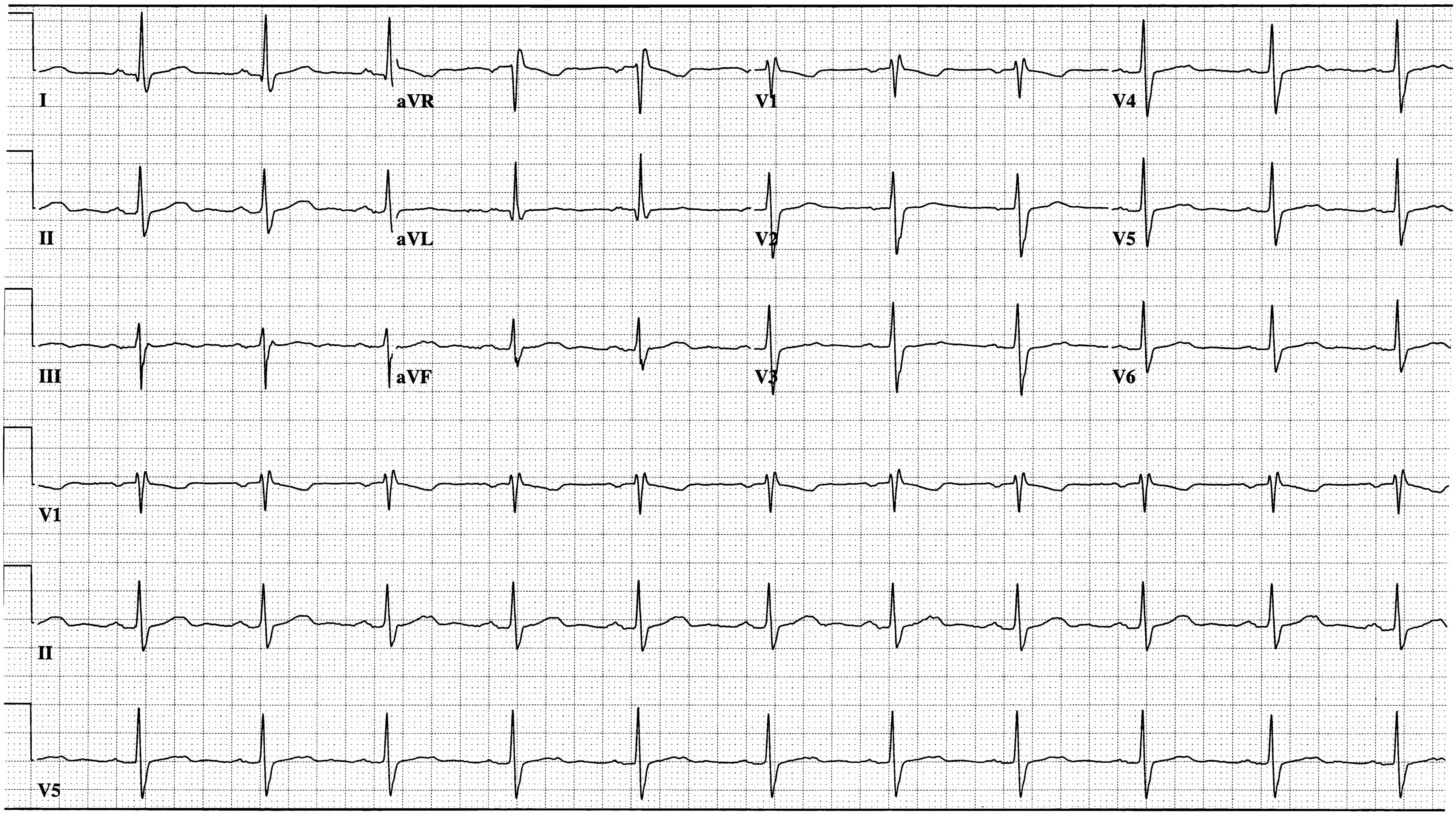
U wave: ______

Diagnosis: ______



ECG Review 96

Atrial rate:	QRS complex:	ST segment:
Ventricular rate:	Axis:	T wave:
Rhythm:	Duration:	QT interval:
P wave:	Voltage:	U wave:
PR interval:	Morphology:	Diagnosis:



ECG Review 97

Atrial rate: ____________________

Ventricular rate: ____________________

Rhythm: ____________________

P wave: ____________________

PR interval: ____________________

QRS complex:

Axis: ____________________

Duration: ____________________

Voltage: ____________________

Morphology: ____________________

ST segment: ____________________

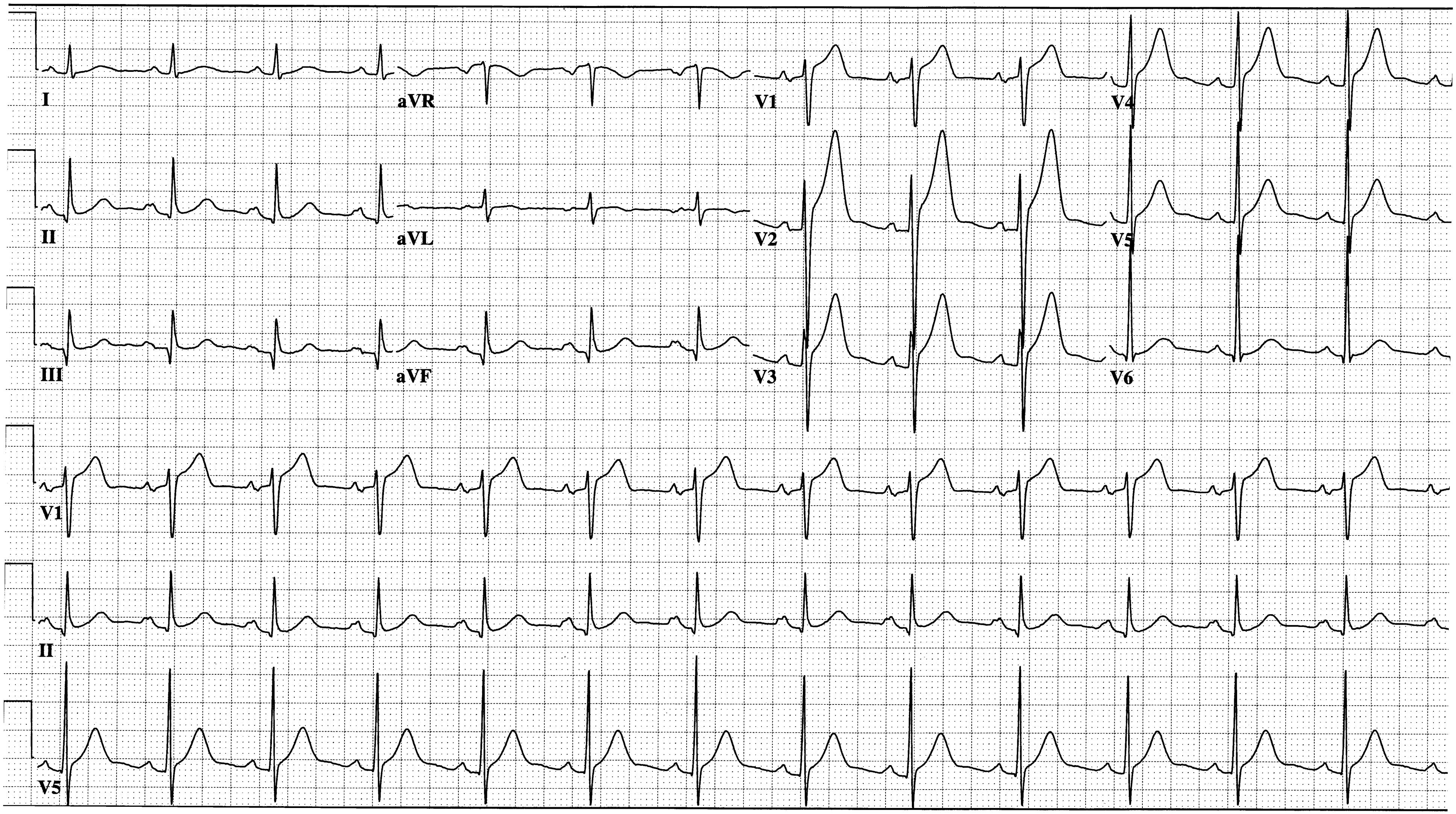
T wave: ____________________

QT interval: ____________________

U wave: ____________________

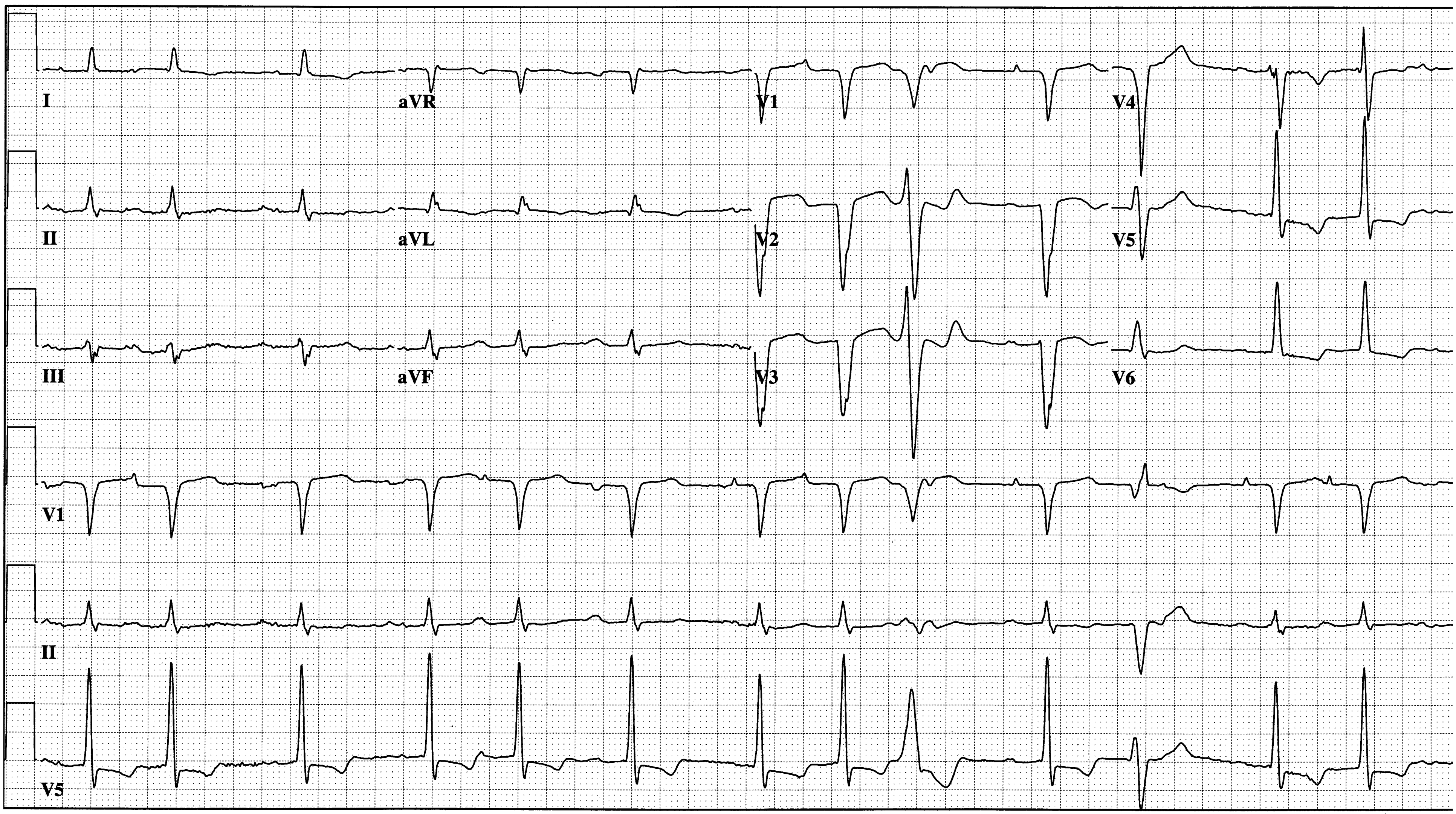
Diagnosis: ____________________

____



ECG Review 98

Atrial rate:	QRS complex:	ST segment:
Ventricular rate:	Axis:	T wave:
Rhythm:	Duration:	QT interval:
P wave:	Voltage:	U wave:
PR interval:	Morphology:	Diagnosis:

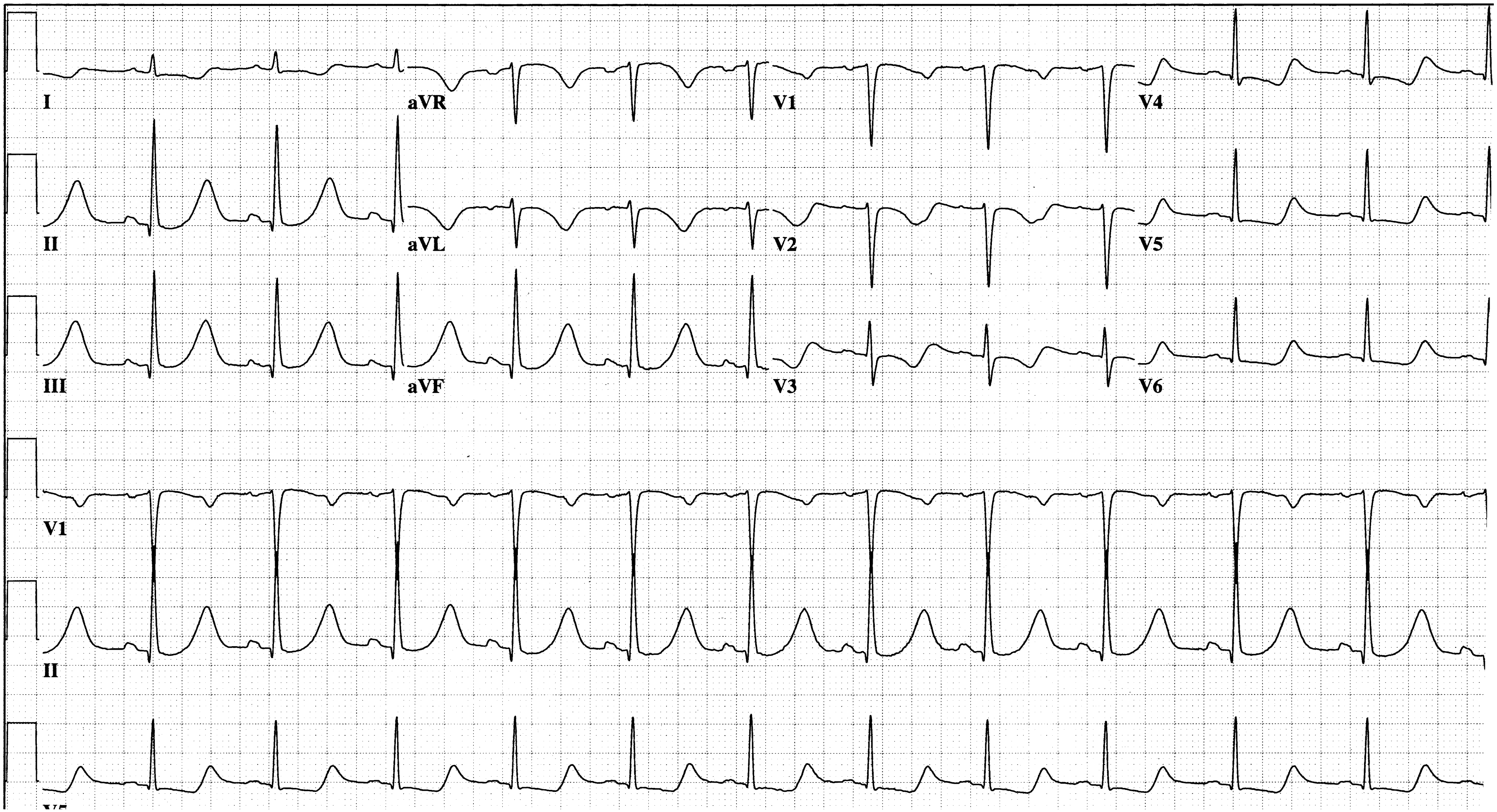


ECG Review 99

Atrial rate: ____________________
Ventricular rate: ____________________
Rhythm: ____________________
P wave: ____________________
PR interval: ____________________

QRS complex:
Axis: ____________________
Duration: ____________________
Voltage: ____________________
Morphology: ____________________

ST segment: ____________________
T wave: ____________________
QT interval: ____________________
U wave: ____________________
Diagnosis: ____________________
____

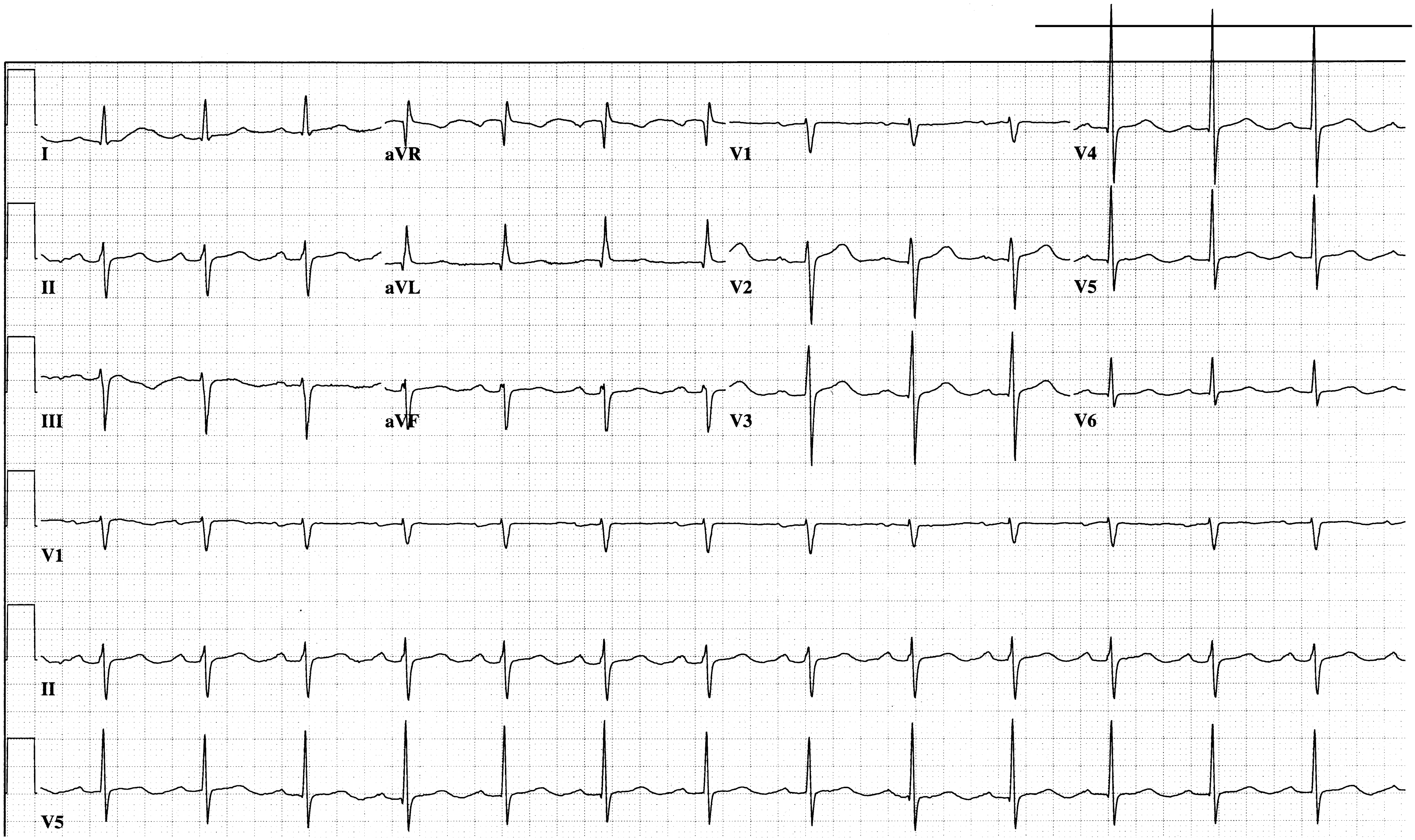


ECG Review 100

Atrial rate: ______
Ventricular rate: ______
Rhythm: ______
P wave: ______
PR interval: ______

QRS complex:
Axis: ______
Duration: ______
Voltage: ______
Morphology: ______

ST segment: ______
T wave: ______
QT interval: ______
U wave: ______
Diagnosis: ______



Interpretations of Sample Tracings

ECG Review 1

Atrial rate:
Ventricular rate: 142
Rhythm: Atrial flutter?
P wave:
PR interval:
QRS complex:
  Axis: –45°
  Duration: 175 msec, LBBB
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval: 360 msec
U wave:
Diagnosis: This is a wide complex tachycardia with RS complexes in the precordial leads. The RS intervals are slightly less than 100 msec. AV dissociation cannot be discerned. There are monophasic R waves in I and V6 consistent with a true LBBB. Therefore, this is consistent with a supraventricular tachycardia with LBBB aberrancy. Since the ventricular rate is 142, the rhythm is likely to be atrial flutter with 2:1 AV block

ECG Review 2

Atrial rate: 68
Ventricular rate: 68
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: –60°
  Duration: 90 msec
  Voltage: Normal
  Morphology: Q waves in II, III, and aVF, and tall R waves in V1 and V2
ST segment: Normal
T wave: T wave inversion in II, aVF, V5 and V6
QT interval: 430 msec
U wave:
Diagnosis: Sinus rhythm with a previous inferoposterior MI

ECG Review 3

Atrial rate: 288
Ventricular rate: 144

Rhythm: Atrial flutter with 2:1 AV block
P wave:
PR interval:
QRS complex:
  Axis: 0°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 280 msec
U wave:
Diagnosis: Atrial flutter with 2:1 AV block. The flutter waves can be seen in several leads and the ventricular rate is ideal for flutter

ECG Review 4

Atrial rate: 53
Ventricular rate: 53
Rhythm: Sinus bradycardia
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: 130°
  Duration: 100 msec, LPFB
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Inverted T wave in aVL
QT interval: 450 msec
U wave:
Diagnosis: Sinus bradycardia with a left posterior fascicular block (axis >100°, deep S wave in I and a tiny Q wave in III)

ECG Review 5

Atrial rate: 61
Ventricular rate: 61
Rhythm: Sinus rhythm with second degree SA block type 1
P wave: Normal
PR interval: 190 msec
QRS complex:
  Axis: 0°
  Duration: 90 msec
  Voltage: Normal
  Morphology: Normal

ST segment: Normal
T wave: Normal
QT interval: 400 msec
U wave:
Diagnosis: Sinus rhythm with second degree SA block type 1. There is group beating of the QRS complexes, the P waves have similar morphology, and the PR intervals are identical

ECG Review 6

Atrial rate:
Ventricular rate: 52
Rhythm: Junctional rhythm
P wave:
PR interval:
QRS complex:
  Axis: 60°
  Duration: 115 msec
  Voltage:
  Morphology: Delayed precordial transition of the R waves
ST segment: Normal
T wave: Inverted in I and aVL
QT interval: 430 msec
U wave: Prominent U waves in the precordial leads
Diagnosis: Junctional rhythm with probably a retrograde P wave seen best in II, and left axis deviation

ECG Review 7

Atrial rate: 110
Ventricular rate: 110
Rhythm: Sinus tachycardia
P wave: Right atrial abnormality
PR interval: 140 msec
QRS complex:
  Axis: 90°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Inverted in aVL
QT interval: 350 msec
U wave:
Diagnosis: Sinus tachycardia with right atrial abnormality

ECG Review 8

Atrial rate:
Ventricular rate: 103
Rhythm: Atrial fibrillation with rapid ventricular response
P wave:
PR interval:
QRS complex:
  Axis: 70°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Nonspecific changes
QT interval: 310 msec
U wave:
Diagnosis: Atrial fibrillation with a very course baseline, particularly in V1

ECG Review 9

Atrial rate:
Ventricular rate: 104
Rhythm: Atrial fibrillation with rapid ventricular response
P wave:
PR interval:
QRS complex:
  Axis: –35°
  Duration: 125 msec, IVCD
  Voltage:
  Morphology:
ST segment: Normal
T wave: Normal
QT interval: 350 msec
U wave:
Diagnosis: This is atrial fibrillation as evidenced by an irregular ventricular response and no obvious P waves. There is also left axis deviation and a nonspecific IVCD

ECG Review 10

Atrial rate: 65
Ventricular rate: 65
Rhythm: Sinus rhythm with intermittent atrial pacing
P wave: Paced
PR interval: 180 msec
QRS complex:

Axis: 100°
Duration: 105 msec
Voltage: Increased in V1 and V2
Morphology: Tall R waves in V1 and V2, and small Q waves in V2 to V5 and the inferior leads

ST segment: Slight ST segment elevation in V1 to V3
T wave: Deeply inverted in V1 to V3
QT interval: 440 msec
U wave:
Diagnosis: Atrial pacing, right axis deviation, and very prominent R waves in V1 and V2 suggest RVH. An alternative diagnosis would be incomplete RBBB. There may be an old anterior MI.

ECG Review 11

Atrial rate:
Ventricular rate: 134
Rhythm: Atrial fibrillation with rapid ventricular response
P wave:
PR interval:
QRS complex:
Axis: 130°
Duration: 150 msec, RBBB, LPFB
Voltage: Normal
Morphology: Normal

ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 320 msec
U wave:
Diagnosis: Atrial fibrillation with rapid ventricular response, right axis deviation, RBBB, and left posterior fascicular block (right axis deviation > 100°, deep S wave in I, and tiny Q wave in III)

ECG Review 12

Atrial rate:
Ventricular rate: 67
Rhythm: Atrial fibrillation
P wave:
PR interval:
QRS complex:
Axis: –80°
Duration: 140 msec, RBBB
Voltage: Low
Morphology: Apparent inferior and anterior MIs

ST segment: Nonspecific changes

T wave: Nonspecific changes
QT interval: 380 msec
U wave:
Diagnosis: Atrial fibrillation with low voltage, far left axis deviation, RBBB, and apparently inferior and anterior MIs. The triad of atrial fibrillation, low voltage, and a wide QRS complex, even with apparent infarct patterns, is frequently seen in patients with amyloidosis, as is the case in this patient

ECG Review 13

Atrial rate: 90
Ventricular rate: 90
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: −60°
  Duration: 90 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Diffuse downsloping ST segment depression.
T wave: Normal
QT interval: 360 msec
U wave:
Diagnosis: Sinus rhythm with left axis deviation and diffuse ST segment depression consistent with ischemia

ECG Review 14

Atrial rate: 135
Ventricular rate: 27
Rhythm: Sinus tachycardia with 5:1 AV block
P wave: Normal
PR interval:
QRS complex:
  Axis: −60°
  Duration: 100 msec, incomplete RBBB
  Voltage: Normal
  Morphology: Possible inferoposterior MI
ST segment: Nonspecific changes
T wave: Deeply inverted in several leads
QT interval: 680 msec
U wave:
Diagnosis: Sinus tachycardia with high grade AV block, incomplete RBBB, and diffuse ST-T wave changes in a patient with ischemia and heart failure. He may have had a previous inferoposterior MI, in spite of the tiny R waves in II, III, and aVF

ECG Review 15

Atrial rate: 88
Ventricular rate: 88
Rhythm: Sinus rhythm with a competing electronic ventricular pacemaker
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: 80°
  Duration: 100 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 370 msec
U wave:
Diagnosis: Sinus rhythm with a competing ventricular pacemaker. There are retrograde P waves following each of the paced beats. The large pacemaker spike is consistent with a unipolar lead

ECG Review 16

Atrial rate:
Ventricular rate: 195
Rhythm: Supraventricular tachycardia
P wave:
PR interval:
QRS complex:
  Axis: −80°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Slight depression in the inferior leads
T wave: Normal
QT interval: 240 msec
U wave:
Diagnosis: A supraventricular tachycardia which is slightly irregular and therefore probably represents atrial fibrillation with rapid ventricular response. Continuous ECG monitoring accompanied buy intravenous adenosine administration would likely be diagnostic

ECG Review 17

Atrial rate: 145
Ventricular rate: 145
Rhythm: AVNRT of the common or typical form

P wave:
PR interval:
QRS complex:
Axis: 60°
Duration: 90 msec
Voltage: Voltage criteria for LVH in the precordial leads
Morphology: Normal
ST segment: ST segment depression in the inferior leads
T wave: Normal
QT interval: 320 msec
U wave:
Diagnosis: AVNRT of the common or typical form and LVH by voltage criteria (notice that the chest leads are at half standard)

ECG Review 18

Atrial rate:
Ventricular rate: 94
Rhythm: Atrial fibrillation
P wave:
PR interval:
QRS complex:
Axis: −80°
Duration: 160 msec, RBBB
Voltage: Normal
Morphology: Q waves in III, aVF, and V1 to V3
ST segment:
T wave:
QT interval: 310 msec
U wave:
Diagnosis: Atrial fibrillation with left axis deviation, RBBB, and old inferior and anteroseptal MIs. The R wave of the expected RSR' in V1 has been replaced by a Q wave due to the anteroseptal MI

ECG Review 19

Atrial rate:
Ventricular rate: 170
Rhythm: Ventricular tachycardia
P wave:
PR interval:
QRS complex:
Axis: 150°
Duration: 160 msec
Voltage:
Morphology:

ST segment:
T wave:
QT interval:
U wave:
Diagnosis: This is a wide complex tachycardia with RS complexes in the precordial leads that, particularly in V6, are greater than 100 msec consistent with ventricular tachycardia

ECG Review 20

Atrial rate:
Ventricular rate: 62
Rhythm: Sinus rhythm with nonconducted PACs and first degree AV block
P wave: Normal
PR interval: 240 msec
QRS complex:
  Axis: 60°
  Duration: 110 msec
  Voltage: Normal
  Morphology: Small Q waves in II, III and aVF possibly indicating a previous inferior MI
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 410 msec
U wave: Present in V1 and V2
Diagnosis: Sinus rhythm with frequent nonconducted PACs. Notice the peaked T waves in the V1 rhythm strip preceding each pause that indicate a superimposed P wave

ECG Review 21

Atrial rate:
Ventricular rate: 131
Rhythm: Probably sinus tachycardia with an electronic ventricular pacemaker
P wave:
PR interval:
QRS complex:
  Axis:
  Duration:
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval:
U wave:

Diagnosis: There is clearly an electronic ventricular pacemaker. The only issue is whether this rhythm is sinus tachycardia with atrial sensing and ventricular pacing or pacemaker mediated tachycardia. Interrogation of the pacemaker or application of an external magnet while obtaining a continuous ECG would clarify this situation

ECG Review 22

Atrial rate:
Ventricular Rate: 124
Rhythm: VT
P wave:
PR interval: 340 msec
QRS complex:
  Axis: –80°
  Duration: 190 msec
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval:
U wave:
Diagnosis: This is a wide complex tachycardia with a brief interval of what appears to be sinus rhythm with a long first degree AV block. The wide complex rhythm does not have any true RS complexes, consistent with episodic ventricular tachycardia

ECG Review 23

Atrial rate: 94
Ventricular rate: 94
Rhythm: Sinus rhythm
P wave: Normal
PR interval: Normal
QRS complex:
  Axis: 45°
  Duration: 100 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Diffuse inferior and anterolateral ST segment depression
T wave: Normal
QT interval: 370 msec
U wave:
Diagnosis: Sinus rhythm with diffuse ST segment depression consistent with ischemia

ECG Review 24

Atrial rate: 75
Ventricular rate: 75
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: 10°
  Duration: 100 msec
  Voltage: LVH
  Morphology: Previous inferolateral MI
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 340 msec
U wave:
Diagnosis: Sinus rhythm, voltage criteria for LVH in I and aVL and an obvious old inferior MI with probable lateral extension

ECG Review 25

Atrial rate: 98
Ventricular rate: 98
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 160
QRS complex:
  Axis: –90°
  Duration: 110
  Voltage: Normal
  Morphology: Deep Q waves in II, III, aVF, V6, and tall R waves in V1 and V2
ST segment: Normal
T wave: Inverted in I and aVL
QT interval: 370
U wave:
Diagnosis: Sinus rhythm with an extensive previous MI involving the inferior, posterior, and lateral regions of the left ventricle

ECG Review 26

Atrial rate: 80
Ventricular rate: 40
Rhythm: Sinus rhythm with complete heart block and a junctional escape rhythm
P wave: Normal
PR interval:

QRS complex:
Axis: Indeterminate
Duration: 160, RBBB
Voltage: Normal
Morphology:
ST segment:
T wave: Deeply inverted symmetrical T waves in the precordial leads
QT interval: 760
U wave:
Diagnosis: Sinus rhythm with complete heart block and a junctional or ventricular escape with RBBB. This patient presented with a newly diagnosed dilated cardiomyopathy

ECG Review 27

Atrial rate: 70
Ventricular rate: 70
Rhythm: Sinus rhythm with first degree AV block
P wave: Normal
PR interval: 260 msec
QRS complex:
Axis: 120°
Duration: 220 msec, RBBB, LPFB
Voltage: Normal
Morphology:
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 460 msec
U wave:
Diagnosis: Sinus rhythm with first degree AV block, RBBB, and left posterior fascicular block (right axis deviation > 100°, small Q wave in III)

ECG Review 28

Atrial rate: 47
Ventricular rate: 47
Rhythm: Sinus bradycardia
P wave: Normal
PR interval: 140 msec
QRS complex:
Axis: 90°
Duration: 100 msec
Voltage: Nearly LVH
Morphology: Normal
ST segment: Nonspecific changes
T wave: Inverted in aVL
QT interval: 500 msec

U wave: Prominent in several leads
Diagnosis: Sinus bradycardia with “sagging” ST segments typically seen in patients receiving digitalis. There are also prominent U waves, possibly due to incipient LVH

ECG Review 29

Atrial rate:
Ventricular Rate: 165
Rhythm: VT
P wave:
PR interval:
QRS complex:
  Axis: −80°
  Duration: 200 msec
  Voltage:
  Morphology:
  ST segment:
T wave:
QT interval:
U wave:
Diagnosis: This is a wide complex tachycardia with QS waves in all the precordial leads except perhaps V1. The RS interval in V1 is greater than 100 msec, consistent with ventricular tachycardia

ECG Review 30

Atrial rate: 60
Ventricular rate: 60
Rhythm: Ectopic atrial rhythm
P wave: Inverted in the inferior leads
PR interval: 140 msec
QRS complex:
  Axis: Indeterminate
  Duration: 80 msec
  Voltage: **Low**
  Morphology: Persistent deep S waves across the precordial leads
ST segment: Normal
T wave: Nonspecific changes
QT interval: 400 msec
U wave:
Diagnosis: Ectopic atrial rhythm, right axis deviation, low voltage and deep persistent S waves across the precordial leads consistent with pulmonary disease

ECG Review 31

Atrial rate: 72
Ventricular rate: 72
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: 60°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Low voltage in the precordial leads
ST segment: Normal
T wave: Normal
QT interval: 380 msec
U wave:
Diagnosis: Sinus rhythm with low voltage in the precordial leads and artifact in the early part of the ECG. The rate of the artifact is about 300, which is typical for a Parkinsonian tremor

ECG Review 32

Atrial rate: 58
Ventricular rate: 58
Rhythm: Sinus bradycardia
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: 110°
  Duration: 110 msec, LPFB
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 430 msec
U wave:
Diagnosis: Sinus bradycardia, right axis deviation, and left posterior fascicular block (axis > 100°, deep S wave in I, and tiny Q wave in III)

ECG Review 33

Atrial rate:
Ventricular rate: 180
Rhythm: VT
P wave:

PR interval:
QRS complex:
  Axis: −30°
  Duration: 170 msec
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval:
U wave:
Diagnosis: This is a wide complex tachycardia with RS complexes in V1 to, possibly, V3. The RS interval in V2 is clearly greater than 100 msec, consistent with ventricular tachycardia

ECG Review 34

Atrial rate:
Ventricular rate: 60
Rhythm: Atrial fibrillation
P wave:
PR interval:
QRS complex:
  Axis: 90°
  Duration: 160 msec, LBBB
  Voltage:
  Morphology:
ST segment:
T wave: Extremely peaked in V1 and V3
QT interval: 530
U wave:
Diagnosis: Atrial fibrillation with LBBB and dramatic peaked T waves in V1 and V3 (the V1 and V2 leads are probably reversed) in a patient with hyperkalemia (K = 8.4 mmol/l)

ECG Review 35

Atrial rate: 58
Ventricular rate: 58
Rhythm: Sinus bradycardia
P wave: Normal
PR interval: 120 msec
QRS complex:
  Axis: 60°
  Duration:
  Voltage:
  Morphology:

ST segment:
T wave:
QT interval:
U wave:
Diagnosis: Sinus bradycardia with WPW. Note the short PR interval and the delta waves in multiple leads. The Q waves in aVL and the tall R wave in V1 do not indicate a previous MI, and the excessive voltage in the precordial leads cannot be interpreted as LVH

ECG Review 36

Atrial rate: 63
Ventricular rate: 63
Rhythm: Sinus rhythm with occasional PVCs
P wave: Normal
PR interval: 180 msec
QRS complex:
  Axis: 60°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 420 msec
U wave:
Diagnosis: Sinus rhythm with occasional PVCs with a compensatory pause

ECG Review 37

Atrial rate:
Ventricular rate: 80
Rhythm: Accelerated junctional rhythm
P wave:
PR interval:
QRS complex:
  Axis: 95°
  Duration: 105 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 380 msec
U wave:
Diagnosis: Accelerated junctional rhythm

ECG Review 38

Atrial rate: 128
Ventricular rate: 128
Rhythm: Ectopic atrial tachycardia
P wave: Inverted in the inferior leads
PR interval: 160 msec
QRS complex:
  Axis: 70°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 320 msec
U wave:
Diagnosis: Ectopic atrial tachycardia as evidenced by an abnormal P wave axis

ECG Review 39

Atrial rate:
Ventricular rate: 175
Rhythm: VT
P wave:
PR interval:
QRS complex:
  Axis: 240°
  Duration: 130 msec, RBBB
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval:
U wave:
Diagnosis: This is a wide complex tachycardia with RS complexes in V4 and V5. The RS interval is less than 100 msec. AV dissociation cannot be discerned. This rhythm has a RBBB morphology and there is a monophasic R wave in V1 and a QS complex in V6. These features are consistent with ventricular tachycardia

ECG Review 40

Atrial rate: 320
Ventricular rate: 160
Rhythm: Atrial flutter with 2:1 AV block
P wave:

PR interval:
QRS complex:
  Axis: 60°
  Duration: 100 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 280 msec
U wave:
Diagnosis: Atrial flutter with 2:1 AV block

ECG Review 41

Atrial rate: 90
Ventricular rate: 90
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 200
QRS complex:
  Axis: 75°
  Duration: 80
  Voltage: Normal
  Morphology: Normal
ST segment: ST segment elevation in V2 to V5 and II, III, and aVF
T wave: Peaked in several leads
QT interval: 340
U wave:
Diagnosis: Sinus rhythm with ST segment elevation and peaked T waves in a patient with moderate hyperkalemia (K = 6.8 mmol/l)

ECG Review 42

Atrial rate: 80
Ventricular rate: 80
Rhythm: sinus rhythm
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: 45°
  Duration: 100 msec
  Voltage: Voltage criteria for LVH in the precordial leads
  Morphology: Normal
ST segment: Normal
T wave: Deep T wave inversion in multiple leads, probably associated with LVH

QT interval: 400 msec
U wave:
Diagnosis: Sinus rhythm with voltage criteria for LVH and associated repolarization abnormalities

ECG Review 43

Atrial rate: 90
Ventricular rate: 90
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 140 msec
QRS complex:
  Axis: 70°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Slightly prominent R waves in V1 and V2
ST segment: Profound ST segment depression in V2 to V4
T wave: Normal
QT interval: 340 msec
U wave:
Diagnosis: Sinus rhythm with ST segment depression probably indicating anterior ischemia. Another possibility would be a true posterior MI as evidenced by the early R wave transition in the precordial leads. Cardiac imaging (e.g. with echocardiography) would localize the zone of ischemia

ECG Review 44

Atrial rate: 260
Ventricular rate: 130
Rhythm: Atrial flutter with 2:1 AV block
P wave:
PR interval:
QRS complex:
  Axis: 0°
  Duration: 180, RBBB
  Voltage: Normal
  Morphology: Normal
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 360 msec
U wave:
Diagnosis: Atrial flutter with 2:1 AV conduction and RBBB. The flutter waves can be seen best in II

ECG Review 45

Atrial rate: 80
Ventricular rate: 58
Rhythm: Sinus rhythm with second degree AV block type 1
P wave: Normal
PR interval:
QRS complex:
  Axis: Right superior axis deviation
  Duration: 125 msec, RBBB
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 460 msec
U wave:
Diagnosis: Sinus rhythm with second degree AV block type 1 and RBBB

ECG Review 46

Atrial rate: 34
Ventricular rate: 36
Rhythm: Sinus bradycardia with a competing junctional escape rhythm
P wave:
PR interval:
QRS complex:
  Axis: 30°
  Duration: 100 msec
  Voltage: LVH
  Morphology: Normal
ST segment: ST segment elevation in V2 and V3
T wave: T wave inversion in aVL, V5 and V6
QT interval: 480 msec
U wave: Prominent U wave in V2 and V3
Diagnosis: Severe sinus bradycardia with a competing and slightly faster junctional escape rhythm. This is an example of isorhythmic AV dissociation in which the two rhythms are occurring at almost identical rates. Normal AV nodal conduction would be apparent if the sinus rate increased. There is also voltage criteria for LVH and ST-T wave changes probably representing the repolarization abnormalities of LVH. The prominent U waves are also likely to be due to LVH

ECG Review 47

Atrial rate:
Ventricular rate: 60

Rhythm: Atrial fibrillation with a ventricular pacemaker
P wave:
PR interval:
QRS complex:
  Axis:
  Duration:
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval:
U wave:
Diagnosis: This ECG is quite difficult unless one discerns the tiny pacemaker spikes at the beginning of the QRS complexes in V2 and V3. There is no evidence of atrial activity, so the rhythm is atrial fibrillation with a ventricular pacemaker. There is one normally conducted beat in the middle of the tracing that appropriately inhibits the pacemaker

ECG Review 48

Atrial rate: 40
Ventricular rate: 38
Rhythm: Probable idioventricular rhythm
P wave: Normal
PR interval:
QRS complex:
  Axis: −20°
  Duration: 280 msec
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval: 640 msec
U wave:
Diagnosis: Probable idioventricular rhythm, although in severe hyperkalemia, the P waves of sinus rhythm may disappear, even when atrial systole is present. This patient had a serum potassium of 9.5 mmol/l. If the hyperkalemia worsens, the ECG will deteriorate further into a sine wave configuration

ECG Review 49

Atrial rate: 90
Ventricular rate: 90
Rhythm: Sinus rhythm with PACs
P wave: Normal
PR interval: 180 msec
QRS complex:

Axis: Right upper quadrant
Duration: 100 msec
Voltage: Normal
Morphology: Persistent deep S waves across the precordial leads
ST segment: Normal
T wave: Inverted in aVL
QT interval: 350 msec
U wave:
Diagnosis: Sinus rhythm with PACs, right superior axis deviation, and persistent deep S waves across the precordial leads consistent with pulmonary disease. The tiny Q waves in V2 and V3 probably do not represent and old septal MI

ECG Review 50

Atrial rate:
Ventricular rate: 200
Rhythm: Probably AVNRT of the typical form
P wave:
PR interval:
QRS complex:
Axis: 45°
Duration: 60 msec
Voltage: Normal
Morphology: Normal
ST segment: Diffuse severe ST segment depression
T wave:
QT interval:
U wave:
Diagnosis: A rapid supraventricular tachycardia with what appear to be small P waves following each QRS complex, most easily seen in I, V5 and V6. This is consistent with AVNRT of the common or typical form. The diffuse ST segment depression may indicate ischemia, but frequently accompanies supraventricular tachycardias in patients without coronary disease

ECG Review 51

Atrial rate: 110
Ventricular rate: 110
Rhythm: Sinus tachycardia
P wave: Normal
PR interval: 130 msec
QRS complex:
Axis: 45°
Duration: 60 msec
Voltage: Low
Morphology: Normal

ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 300 msec
U wave:
Diagnosis: Sinus tachycardia with extremely low voltage. Clinically, this patient had obstructive sleep apnea, pulmonary edema, and pleural effusions

ECG Review 52

Atrial rate: 68
Ventricular rate: 68
Rhythm: Sinus rhythm with a first degree AV block
P wave: Normal
PR interval: 400 msec
QRS complex:
  Axis: −70°
  Duration: 140 msec, RBBB, LAFB
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 400 msec
U wave:
Diagnosis: Sinus rhythm with a long first degree AV block, left axis deviation, left anterior fascicular block (left axis deviation ≥ 45°, tiny Q waves in I and aVL, and an IVCD), and RBBB

ECG Review 53

Atrial rate: 58
Ventricular rate: 44
Rhythm: Sinus rhythm with second degree AV block type 1
P wave: Normal
PR interval:
QRS complex:
  Axis: 80°
  Duration: 90 msec
  Voltage: Low
  Morphology: Probable old anteroseptal MI
ST segment: Normal
T wave: T wave inversion in aVL, V1 and V6
QT interval: 500 msec
U wave:
Diagnosis: Sinus rhythm with second degree AV block type 1, occasional PVCs, low voltage, and a probable previous anteroseptal MI

ECG Review 54

Atrial rate:
Ventricular rate: 120
Rhythm: Atrial fibrillation with rapid ventricular response
P wave:
PR interval:
QRS complex:
Axis: 60°
Duration: 100 msec
Voltage: Normal
Morphology: Normal
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 330 msec
U wave:
Diagnosis: Atrial fibrillation with rapid ventricular response with frequent PVCs or, more likely, aberrantly conducted supraventricular beats. It is may be impossible to differentiate aberrantly conducted supraventricular beats from ventricular beats, particularly in atrial fibrillation

ECG Review 55

Atrial rate: 70
Ventricular rate: 70
Rhythm: Sinus rhythm
P wave: Right atrial abnormality
PR interval: 150 msec
QRS complex:
Axis: 100°
Duration: 110 msec
Voltage: Normal
Morphology: Deep persistent S waves across the precordial leads
ST segment: Normal
T wave: Normal
QT interval: 390 msec
U wave:
Diagnosis: Sinus rhythm with obvious right atrial abnormality, right axis deviation, and persistent S waves cross the precordial leads consistent with pulmonary disease

ECG Review 56

Atrial rate:
Ventricular rate: 130 msec

Rhythm: Atrial fibrillation with rapid ventricular response
P wave:
PR interval:
QRS complex:
  Axis: –45°
  Duration: 180 msec, RBBB
  Voltage: Normal
  Morphology: Small Q waves in V1 through V4
ST segment:
T wave:
QT interval: 370 msec
U wave:
Diagnosis: Atrial fibrillation with rapid ventricular response, left axis deviation RBBB, and possible old septal MI

ECG Review 57

Atrial rate: 75
Ventricular rate: 75
Rhythm: Sinus rhythm with frequent PVCs
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: –60°
  Duration: 125 msec, IVCD
  Voltage: Normal
  Morphology: Normal
ST segment: Nonspecific changes
T wave: Normal
QT interval: 400 msec
U wave:
Diagnosis: Sinus rhythm with frequent PVCs, left axis deviation, and a nonspecific IVCD

ECG Review 58

Atrial rate: 340
Ventricular rate: 85
Rhythm: Atrial flutter
P wave:
PR interval:
QRS complex:
  Axis: 60°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal

ST segment: Normal
T wave: Normal
QT interval: 360 msec
U wave:
Diagnosis: Atrial flutter with mostly 4:1 AV conduction and a single PVC

ECG Review 59

Atrial rate: 55
Ventricular rate: 68
Rhythm: Sinus rhythm with a complete competing electronic ventricular pacemaker
P wave: Normal
PR interval:
QRS complex:
  Axis: $-30°$
  Duration: 160 msec, RBBB
  Voltage: Normal
  Morphology:
ST segment:
T wave:
QT interval: 460 msec
U wave:
Diagnosis: Sinus bradycardia with a competing electronic ventricular pacemaker. At times, the P waves are conducted to the ventricles, and at other times, the paced rhythm competes with the sinus mechanism, resulting in fusion beats. The native QRS complexes have RBBB. The ventricular pacemaker is appropriately inhibited by the native complexes. The pacemaker therefore, is functioning in the VVI mode

ECG Review 60

Atrial rate: 75
Ventricular rate: 122
Rhythm: Atrial fibrillation alternating with sinus rhythm
P wave: Normal in sinus rhythm
PR interval: 160 msec
QRS complex:
  Axis: 70°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 380 msec
U wave:

Diagnosis: Atrial fibrillation with rapid ventricular response alternating with brief periods of sinus rhythm. This ECG demonstrates the paroxysmal nature of most atrial fibrillation

ECG Review 61

Atrial rate: 70
Ventricular rate: 70
Rhythm: Sinus rhythm
P wave: Inverted in I and aVL
PR interval: 200 msec
QRS complex:
 Axis: Rightward
 Duration: 80 msec
 Voltage: Low voltage in V3 to V6
 Morphology: Low voltage in the lateral precordial leads, Q waves in I and aVL
ST segment: Normal
T wave: Inverted in I and aVL
QT interval: 340 msec
U wave:
Diagnosis: Sinus rhythm with congenital dextrocardia as evidenced by inverted P waves in I and aVL, right axis deviation and QRS voltage that diminishes across the precordial leads

ECG Review 62

Atrial rate: 76
Ventricular rate: 38
Rhythm: Sinus rhythm with second degree AV block probably type 1
P wave: Normal
PR interval:
QRS complex:
 Axis: $-70°$
 Duration: 160 msec, RBBB, LAFB
 Voltage: Normal
 Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 480 msec
U wave:
Diagnosis: Sinus rhythm with second degree AV block probably type 1, left axis deviation, left anterior fascicular block (left axis deviation $\geq 45°$, a tiny Q wave in aVL, and an IVCD), and RBBB. Since there is 2:1 AV block, it is not possible to state with certainty that this is second degree AV block type 1. However, this diagnosis is much more likely than type 2

ECG Review 63

Atrial rate: Probably 300
Ventricular rate: 150
Rhythm: Probably atrial flutter with 2:1 AV block
P wave:
PR interval:
QRS complex:
  Axis: –45°
  Duration: 130 msec, LBBB
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval: 340 msec
U wave:
Diagnosis: This is a wide complex tachycardia with RS complexes in the precordial leads, none of which are greater than 100 msec. There appear to be two P waves for each QRS complex in V1, and the ventricular rate is appropriate for atrial flutter with 2:1 AV block. Morphology criteria are also in favor of a supraventricular origin with LBBB

ECG Review 64

Atrial rate: 85
Ventricular rate: 54
Rhythm: Sinus rhythm with second degree AV block type 1
P wave: Normal
PR interval:
QRS complex:
  Axis: 45°
  Duration: 100 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Nonspecific T wave changes
QT interval: 540 msec
U wave:
Diagnosis: Sinus rhythm with second degree AV block type 1 with nonspecific T wave changes and a prolonged QT interval

ECG Review 65

Atrial rate:
Ventricular rate: 48
Rhythm: Atrial fibrillation

P wave:
PR interval:
QRS complex:
Axis: –45°
Duration: 180, IVCD
Voltage: LVH voltage in the precordial leads
Morphology:
ST segment: Nonspecific changes
T wave: T wave inversion in I, aVL and V4 to V6
QT interval: 440 msec
U wave: Extremely prominent U waves in the precordial leads
Diagnosis: Atrial fibrillation, left axis deviation, voltage criteria for LVH, nonspecific IVCD, nonspecific ST and T wave changes, and prominent U waves. U waves can occur with LVH, but this patient had hypokalemia as well

ECG Review 66

Atrial rate: 55
Ventricular rate: 55
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 180 msec
QRS complex:
Axis: Indeterminate
Duration: 130 msec, RBBB
Voltage: Normal
Morphology: Prominent Q waves in V1 to V3 and lack of an R wave in V4
ST segment: Hyperacute ST segment elevation in V2 to V5
T wave: T wave inversion in V2 and V3
QT interval: 340 msec
U wave:
Diagnosis: Sinus rhythm with an obvious acute anterior MI and RBBB. The expected R wave of the RSR' in V1 has been lost due to the anteroseptal MI

ECG Review 67

Atrial rate: 65
Ventricular rate: Average of 48
Rhythm: Sinus rhythm with second degree AV block type 1
P wave: Normal
PR interval:
QRS complex:
Axis: 60°
Duration: 160, RBBB
Voltage: Normal
Morphology: Normal

ST segment: Normal
T wave: Normal for RBBB
QT interval: 440 msec
U wave:
Diagnosis: Sinus rhythm with second degree AV block type 1 and RBBB

ECG Review 68

Atrial rate: 100
Ventricular rate: 100
Rhythm: Sinus rhythm
Pwave: Normal
PR interval: 130 msec
QRS complex:
  Axis: –80°
  Duration: 130 msec, RBBB
  Voltage: Normal
  Morphology: Inferior and anterior MIs
ST segment:
T wave:
QT interval: 400 msec
U wave:
Diagnosis: Sinus rhythm with PACs and PVCs. There are Q waves in the inferior leads and the precordial leads consistent with previous inferior and anterior MIs. The anterior MI does not obviate the diagnosis of RBBB. There is also left axis deviation secondary to the inferior MI

ECG Review 69

Atrial rate: 136
Ventricular rate: 136
Rhythm: AVNRT of the common or typical form
P wave:
PR interval:
QRS complex:
  Axis: –60°
  Duration: 120 msec, RBBB, LAFB
  Voltage: LVH
  Morphology: Normal
ST segment:
T wave:
QT interval: 360 msec
U wave:

Diagnosis: This rhythm is AVNRT of the common or typical form, as evidenced by tiny retrograde P waves following the QRS complexes, most readily seen in V2 and V3. There is also left axis deviation, left anterior fascicular block (left axis deviation ≥ 45°, small Q waves in I and aVL, and an IVCD), RBBB, and voltage criteria for LVH in aVL

ECG Review 70

Atrial rate: 80
Ventricular rate: 80
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 200 msec
QRS complex:
 Axis: 75°
 Duration: 80 msec
 Voltage: Normal
 Morphology: Loss of R wave height in V2 to V4.
ST segment: Hyperacute ST segment elevation in V1 to V4 with "reciprocal" ST depression in I, aVL, and V6
T wave: Somewhat peaked in V2 to V4
QT interval: 370 msec
U wave:
Diagnosis: Sinus rhythm with an acute anteroseptal MI

ECG Review 71

Atrial rate:
Ventricular rate: 42
Rhythm: Atrial fibrillation
P wave:
PR interval:
QRS complex:
Axis: 30°
Duration: 110, incomplete LBBB
Voltage: Normal
Morphology: Normal
ST segment: Nonspecific changes
T wave: Inverted in aVL
QT interval: 520 msec
U wave: Fairly prominent in V2 and V3
Diagnosis: Atrial fibrillation with a slow ventricular response and what should probably be called an incomplete LBBB

ECG Review 72

Atrial rate: 125
Ventricular rate: 125
Rhythm: Sinus tachycardia
P wave: Normal
PR interval: 120 msec
QRS complex:
  Axis: −30°
  Duration: 150, LBBB
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval: 360 msec
U wave:
Diagnosis: This is a wide complex tachycardia with RS complexes in the precordial leads, none of which is greater than 100 msec. There appears to be regular P waves, best seen in V1 and II, preceding each QRS complex. The morphology criteria favor LBBB aberrancy. This is sinus tachycardia with LBBB

ECG Review 73

Atrial rate: 107
Ventricular rate: 107
Rhythm: Sinus tachycardia
P wave: Normal
PR interval: 130 msec
QRS complex:
  Axis: 45°
  Duration: 60 msec
  Voltage: Low
  Morphology: Normal
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 300 msec
U wave:
Diagnosis: Sinus tachycardia and low voltage in this patient with morbid obesity

ECG Review 74

Atrial rate:
Ventricular rate: 70
Rhythm: Accelerated idioventricular rhythm
P wave: Retrograde P waves are apparent following each QRS complex

PR interval:
QRS complex:
 Axis: −80°
 Duration: 220 msec
 Voltage:
 Morphology:
ST segment:
T wave:
QT interval: 560 msec
U wave:
Diagnosis: A wide complex rhythm with retrograde P waves following each QRS complex consistent with an accelerated idioventricular rhythm. This could also represent a ventricularly paced rhythm with the pacing spikes being unapparent on this tracing

ECG Review 75

Atrial rate: 100
Ventricular rate: 100
Rhythm: Accelerated junctional rhythm
P wave: Abnormal axis and morphology
PR interval: 100 msec
QRS complex:
 Axis: 60°
 Duration: 60 msec
 Voltage: Normal
 Morphology: Normal
ST segment: Normal
T wave: T wave flattening in several leads
QT interval: 340 msec
U wave:
Diagnosis: This is an accelerated junctional rhythm as indicated by an abnormal P wave with a very short PR interval. There is also one PVC. This rhythm is consistent with digitalis toxicity

ECG Review 76

Atrial rate:
Ventricular rate: 48
Rhythm: Atrial fibrillation
P wave:
PR interval:
QRS complex:
 Axis: 0°
 Duration: 100 msec
 Voltage: Voltage criteria for LVH in I
 Morphology: Normal

ST segment: Normal
T wave: Nonspecific changes
QT interval: 440 msec
U wave:
Diagnosis: Atrial fibrillation with a slow ventricular response and voltage criteria for LVH

ECG Review 77

Atrial rate: 128
Ventricular rate: 128
Rhythm: AVNRT of the common or typical form
P wave:
PR interval:
QRS complex:
  Axis: 60°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 310 msec
U wave:
Diagnosis: This is a supraventricular tachycardia with small retrograde P waves immediately following the QRS complexes, consistent with the common or typical form of AVNRT

ECG Review 78

Atrial rate: 57
Ventricular rate: 57
Rhythm: Sinus bradycardia with first degree AV block
P wave: Normal
PR interval: 220 msec
QRS complex:
  Axis: –60°
  Duration: 100 msec
  Voltage: Normal
  Morphology: Prominent Q waves in V1 to V3
ST segment: Hyperacute ST segment elevation in V1 to V6, I, and aVL
T wave: Normal
QT interval: 430 msec
U wave:
Diagnosis: Sinus bradycardia, first degree AV block, left axis deviation and evidence of an acute extensive anterior and lateral MI

ECG Review 79

Atrial rate: 60
Ventricular rate: 33
Rhythm: Sinus rhythm with second degree AV block type 1
P wave: Normal
PR interval:
QRS complex:
  Axis: −45°
  Duration: 200 msec, LBBB
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval:
U wave:
Diagnosis: Sinus rhythm with second degree AV block type 1 and LBBB

ECG Review 80

Atrial rate: 58
Ventricular rate: 58
Rhythm: Sinus bradycardia
P wave: Normal
PR interval: 180 msec
QRS complex:
  Axis: −20°
  Duration: 90 msec
  Voltage: Normal
  Morphology: Q waves in leads II, III and aVF
ST segment: Hyperacute ST segment elevation in the inferior leads with concomitant ST depression in I and aVL
T wave: Normal
QT interval: 400 msec
U wave:
Diagnosis: Sinus bradycardia with an acute inferior MI

ECG Review 81

Atrial rate:
Ventricular rate: 107
Rhythm: Atrial fibrillation with rapid ventricular response
P wave:
PR interval:
QRS complex:

Axis: 30°
Duration: 100 msec
Voltage: Normal
Morphology: Small RSR' complex in V1 and deep S wave in V6 ST
ST segment: Hyperacute ST segment elevation in II, III, and aVF with ST depression in I and aVL
T wave:
QT interval: 360 msec
U wave:
Diagnosis: Atrial fibrillation with rapid ventricular response and an acute inferior MI

ECG Review 82

Atrial rate: 75
Ventricular rate: 75
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 180 msec
QRS complex:
Axis: 60°
Duration: 160 msec, LBBB
Voltage:
Morphology:
ST segment:
T wave:
QT interval: 440 msec
U wave:
Diagnosis: Sinus rhythm with LBBB

ECG Review 83

Atrial rate: 75
Ventricular rate: 52
Rhythm: Sinus rhythm with complete heart block and a junctional escape rhythm
P wave: Normal
PR interval:
QRS complex:
Axis: 0°
Duration: 90 msec
Voltage: Normal
Morphology: Q waves are present in III and aVF
ST segment: ST segment elevation in II, III, aVF, V5 and V6 with ST depression in I and aVL
T wave: Normal
QT interval: 540 msec
U wave:

Diagnosis: Sinus rhythm with complete heart block and an acute inferior MI that is almost certainly responsible for the AV conduction abnormality.

ECG Review 84

Atrial rate: 65
Ventricular rate: 65
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 140 msec
QRS complex:
  Axis: 70°
  Duration: 95 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Diffuse ST segment depression
T wave: Broad and slurred
QT interval: 630 msec
U wave:
Diagnosis: Sinus rhythm with diffuse ST and T wave changes and a prolonged QT interval in a patient with profound hypokalemia (K = 1.8 mmol/l)

ECG Review 85

Atrial rate: 76
Ventricular rate: 76
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 160 msec
QRS complex:
  Axis: Right superior axis deviation
  Duration: 115 msec
  Voltage:
  Morphology: Q waves in I, II, III, aVF, V5 and V6 and tall R waves in V1 and V2
ST segment: Normal
T wave: Inverted in I and aVL
QT interval: 400 msec
U wave:
Diagnosis: Sinus rhythm with a previous inferoposterior and lateral MIs

ECG Review 86

Atrial rate: 72
Ventricular rate: 72
Rhythm: Sinus rhythm

P wave: Possible right atrial abnormality in V1
PR interval: 200 msec
QRS complex:
  Axis: 90°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Tall R waves in V1 and V2
ST segment: Normal
T wave: Inverted in aVL
QT interval: 360 msec
U wave:
Diagnosis: Sinus rhythm with a vertical axis, possible right atrial abnormality, and tall R waves in V1 and V2 consistent with RVH

ECG Review 87

Atrial rate:
Ventricular rate: 129
Rhythm: Probable sinus tachycardia
P wave:
PR interval:
QRS complex:
  Axis: −70°
  Duration: 150 msec
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval:
U wave:
Diagnosis: This is a wide complex tachycardia with RS complexes in V2 – V6. All of the RS intervals are less than 100 msec. P waves appear to precede each QRS complex in V1 and are occasionally seen in II. Morphology criteria of this RBBB-like rhythm favor ventricular tachycardia, however, because of the P waves, this rhythm is most likely to be sinus tachycardia with RBBB and left anterior fascicular block

ECG Review 88

Atrial rate: 48
Ventricular rate: 24
Rhythm: Severe sinus bradycardia with second degree AV block
P wave: Normal
PR interval: 440 msec
QRS complex:
  Axis: −80°
  Duration: 200 msec

Voltage:
Morphology: LBBB
ST segment: Nonspecific changes
T wave: Nonspecific changes
QT interval: 900 msec
U wave: Prominent U waves in the precordial leads
Diagnosis: Severe sinus bradycardia, second degree AV block (type unknown), very wide QRS complex, long QT interval, and a prominent U wave in a patient with severe hyperkalemia

ECG Review 89

Atrial rate: 55
Ventricular rate: 55
Rhythm: Sinus bradycardia
P wave: Normal
PR interval: 160 msec
QRS complex:
Axis: 60°
Duration: 80 msec
Voltage: Normal
Morphology: Normal
ST segment: Diffuse ST segment elevation
T wave: Normal
QT interval: 390 msec
U wave:
Diagnosis: Sinus bradycardia with wide spread ST segment elevation but no other obvious pathology in an asymptomatic patient with early repolarization

ECG Review 90

Atrial rate: 68
Ventricular rate: 68
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 160 msec
QRS complex:
Axis: 60°
Duration: 80 msec
Voltage: Normal
Morphology: Normal
ST segment: Widespread ST segment depression
T wave: Nonspecific changes
QT interval: 560 msec
U wave:

Diagnosis: Sinus rhythm with diffuse ST segment depression and a prolonged QT interval in a patient with a serum potassium level of 1.8 mmol/l

ECG Review 91

Atrial rate: 128
Ventricular rate: 128
Rhythm: Sinus tachycardia
P wave: Normal
PR interval: 180 msec
QRS complex:
  Axis: 70°
  Duration: 130 msec, RBBB
  Voltage: Normal
  Morphology: Possible old inferior MI
ST segment: Profound widespread ST segment depression consistent with ischemia
T wave: Normal
QT interval: 360 msec
U wave:
Diagnosis: Sinus tachycardia with RBBB, possible old inferior MI, and dramatic ST segment depression consistent with ischemia

ECG Review 92

Atrial rate: 140
Ventricular rate: 140
Rhythm: Probably AVNRT of he uncommon form
P wave:
PR interval:
QRS complex:
  Axis: 0°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment:
T wave:
QT interval: 310 msec
U wave:
Diagnosis: Although the rate of 140 is ideal for atrial flutter with 2:1 AV block, there appears to be only one inverted P wave between each QRS complex consistent with AVNRT of the uncommon form. ECG recording during intravenous adenosine administration would clarify the diagnosis

ECG Review 93

Atrial rate: 70
Ventricular rate: 70
Rhythm: Sinus Rhythm with frequent PVCs and a 3-beat episode of VT
P wave: Normal
PR interval: 160 msec
QRS complex:
Axis: 0°
Duration: 90 msec
Voltage: LVH
Morphology: Normal
ST segment: Repolarization abnormalities consistent with LVH
T wave: Nonspecific T wave changes, probably secondary to LVH
QT interval: 420 msec
U wave:
Diagnosis: Sinus rhythm with frequent PVCs, mainly in a bigeminal pattern with one 3-beat episode of consecutive beats. AV dissociation is apparent during the three beat run. There is also voltage criteria for LVH

ECG Review 94

Atrial rate:
Ventricular rate: 130
Rhythm: Probable atrial flutter
P wave:
PR interval:
QRS complex:
Axis: 60°
Duration: 150, LBBB
Voltage:
Morphology:
ST segment:
T wave:
QT interval: 320 msec
U wave:
Diagnosis: This is a wide complex tachycardia with QS complexes in the precordial leads, none of which have RS intervals greater than 100 msec. AV dissociation cannot be discerned, and at least one and probably two P waves for every QRS complex can be seen in the V1 rhythm strip. There is a monophasic R wave in V6 consistent with LBBB because of the ventricular rate and the two P waves in V1, this is probably atrial flutter with LBBB aberrancy. There are also two PVCs present

ECG Review 95

Atrial rate: 96
Ventricular rate: 48
Rhythm: Sinus rhythm with second degree AV block
P wave: Normal
PR interval:
QRS complex:
  Axis: 60°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: ST segment elevation in the inferior leads and depression in V2
T wave: Rather prominent in the inferior leads
QT interval: 410 msec
U wave: Normal
Diagnosis: Sinus rhythm with second degree AV block, type unknown, probably type 1, in the presence of an acute inferior MI

ECG Review 96

Atrial rate: 68
Ventricular rate: 68
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 190 msec
QRS complex:
  Axis: 0°
  Duration: 110 msec, incomplete RBBB
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 410 msec
U wave:
Diagnosis: Sinus rhythm with a slight prolongation of the QRS complex and an RSR' configuration in V1, consistent with an incomplete RBBB

ECG Review 97

Atrial rate: 80
Ventricular rate: 80
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 180 msec

QRS complex:
  Axis: 60°
  Duration: 80 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Diffuse ST segment elevation
T wave: Prominent upright T waves in V2 to V4
QT interval: 360 msec
U wave: Present in V1 to V5
Diagnosis: Sinus rhythm with diffuse ST segment elevation coupled with PR segment depression in II is consistent with acute pericarditis

ECG Review 98

Atrial rate: 80
Ventricular rate: 80
Rhythm: Wandering atrial pacemaker with occasional PVCs
P wave:
PR interval:
QRS complex:
  Axis: 0°
  Duration: 120 msec, LBBB
  Voltage:
  Morphology:
ST segment:
T wave:
QT interval: 400 msec
U wave:
Diagnosis: Wandering atrial pacemaker as evidenced by multiple P wave morphologies and varying PR intervals. There is also LBBB and PVCs

ECG Review 99

Atrial rate: 65
Ventricular rate: 65
Rhythm: Sinus rhythm
P wave: Normal
PR interval: 170 msec
QRS complex:
  Axis: 60°
  Duration: 90 msec
  Voltage: Normal
  Morphology: Normal
ST segment: Nonspecific changes
T wave: Prominent T waves in the inferior leads
QT interval: 560 msec

U wave:
Diagnosis: Sinus rhythm with a long QT interval in this patient with a congenital long QT syndrome

ECG Review 100

Atrial rate: 80
Ventricular rate: 80
Rhythm: Sinus rhythm with first degree AV block
P wave: Normal
PR interval: 210 msec
QRS complex:
  Axis: –60°
  Duration: 90 msec, LAFB, IVCD
  Voltage: Normal
  Morphology: Normal
ST segment: Normal
T wave: Normal
QT interval: 400 msec
U wave:
Diagnosis: Sinus rhythm with left axis deviation and left anterior fascicular block (left axis deviation ≥ 45°, Tiny Q waves in I and aVL, and a minor IVCD)